S. HRG. 106–1091

S. 2046, NEXT GENERATION INTERNET IN THE PRESIDENT'S FISCAL YEAR 2001 BUDGET

HEARING

BEFORE THE

SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION UNITED STATES SENATE

ONE HUNDRED SIXTH CONGRESS

SECOND SESSION

MARCH 1, 2000

Printed for the use of the Committee on Commerce, Science, and Transportation

U.S. GOVERNMENT PRINTING OFFICE

78–329 FTP WASHINGTON : 2002

For sale by the Superintendent of Documents, U.S. Government Printing Office
Internet: bookstore.gpo.gov Phone: toll free (866) 512–1800; DC area (202) 512–1800
Fax: (202) 512–2250 Mail: Stop SSOP, Washington, DC 20402–0001

SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

ONE HUNDRED SIXTH CONGRESS

SECOND SESSION

JOHN McCAIN, Arizona, *Chairman*

TED STEVENS, Alaska
CONRAD BURNS, Montana
SLADE GORTON, Washington
TRENT LOTT, Mississippi
KAY BAILEY HUTCHISON, Texas
OLYMPIA J. SNOWE, Maine
JOHN ASHCROFT, Missouri
BILL FRIST, Tennessee
SPENCER ABRAHAM, Michigan
SAM BROWNBACK, Kansas

ERNEST F. HOLLINGS, South Carolina
DANIEL K. INOUYE, Hawaii
JOHN D. ROCKEFELLER IV, West Virginia
JOHN F. KERRY, Massachusetts
JOHN B. BREAUX, Louisiana
RICHARD H. BRYAN, Nevada
BYRON L. DORGAN, North Dakota
RON WYDEN, Oregon
MAX CLELAND, Georgia

MARK BUSE, *Staff Director*
MARTHA P. ALLBRIGHT, *General Counsel*
KEVIN D. KAYES, *Democratic Staff Director*
MOSES BOYD, *Democratic Chief Counsel*

SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE

BILL FRIST, Tennessee, *Chairman*

CONRAD BURNS, Montana
KAY BAILEY HUTCHISON, Texas
TED STEVENS, Alaska
SPENCER ABRAHAM, Michigan

JOHN B. BREAUX, Louisiana
JOHN D. ROCKEFELLER IV, West Virginia
JOHN F. KERRY, Massachusetts
BYRON L. DORGAN, North Dakota

CONTENTS

WITNESSES

APPENDIX

S. 2046, NEXT GENERATION INTERNET IN THE PRESIDENTS FISCAL YEAR 2001 BUDGET

WEDNESDAY, MARCH 1, 2000

U.S.SENATE,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, DC.

The subcommittee met, pursuant to notice, at 2:42 p.m., in room SR–253, Russell Senate Office Building, Hon. Bill Frist, chairman of the subcommittee, presiding.

Staff members assigned to this hearing: Elizabeth Prostic, Republican professional staff; and Jean Toal Eisen, Democratic professional staff.

OPENING STATEMENT OF HON. BILL FRIST, U.S. SENATOR FROM TENNESSEE

Senator FRIST. Good afternoon. I want to welcome all of our guests here today.

As the Subcommittee on Science, Technology, and Space convenes its first hearing of the millennium, it is appropriate, I believe, that the Next Generation Internet occupies the prestigious position of being the first hearing before this committee in this millennium. The Internet that is one of the most significant developments of the last decade. Its significance, we all know, is not limited to the new industries that it has created, nor even the new educational opportunities that it affords. The impact of the Internet goes beyond all of those things and really delves into many areas we have not yet explored.

We look back at the development of electronic commerce. We have seen the Internet radically alter the economic landscape of this country. Advances in industries are taking place at breakneck speed, faster and faster each and every day. And at the heart of all of this are really two components, as we all know. One is computers and the advances made in computer sciences, and the other is communications. More and more, we are seeing that the Internet really is the combination of computers and communications going hand in hand.

If we wanted to look at a prototypical success story, I think we should look at the development of the Internet. There are so many different dimensions that we have all either been a part of or studied or touched upon. There is the element of the public and private collaboration. There is the element of the successful commercial application of technology that was first part of Federal mission-directed research. It also shows a successful transition of an operational system from initially the public sector over to the private sector.

But, and what I brag about (because people ask me all the time, "How in the world could you leave medicine to go to the public sector?") is that it shows one of the great investments and payoffs of the public sector: the public investment. And now we have had so much success and so much positive change that we have a whole new set of challenges before us. With the advent of tools that have made the Internet more accessible and more easy to use, there has been an explosion in the amount of traffic that none of us, even 10 years ago, would have predicted.

As computers become more powerful and applications more sophisticated and more advanced, and user interface becomes easier and easier to use and to manipulate, we can look forward, clearly, to an even greater demand for network bandwidth. So we have all the revolutionary advances to date, how they affect our daily lives, but, again, we have to see where we are today, see what challenges there are, what barriers there are in terms of speed and reliability and accessibility and versatility. So I think now, really more than ever, over the last 5 years, it is a useful time to see how we can invest in that next generation, in that next step.

And then, we will see the unfolding of great new technologies. Again, drawing upon my own personal experience, the miraculous rewards that we will see with telemedicine delivering care and the exchange of the benefits of science with communities that simply do not have access today. Distance learning in our lifetime, I have the opportunity of sitting on a board of a major higher education institution, and the dominant theme in our last board meeting was: What about distance learning? How involved do we get? How does it change the culture of learning? How does it change the nature of our great higher educational institutions?

I initially introduced the Next Generation Internet Research Act in 1998. And if we just go back to that period of time and look at enactment, you can go down the list—you see the National Science Foundation since that time has connected over 170 universities and other facilities to look at a test bed with hundredfold increase in network performance. And in the Department of Defense, there is currently a deployment of a test bed with a thousandfold increased performance at over 20 sites to support networking research and applications deployment.

So we look at these areas of real success over the last 3 years, but I also think that it is really clear that there are areas where we have not progressed, where there are certain limitations and certain barriers. In the review of the first 2 years of NGI, the President's Information Technology Advisory Committee recommended that the program should continue to focus on the utility of NGI's giga bandwidth to end users, its increased security and its expanded quality of service.

Importantly, the committee shared Congress' concern that no Federal program specifically addresses the geographical penalty issue and the imposition of costs on users that are different, depending on where they are located, specifically, in rural and less urban areas, where the costs, disproportionately, are greater than the cost imposed on users in more urban locations, locations of higher populations. And this is a disappointment. As I look back, and as we look at that oversight, it is a disappointment that that has not been more adequately addressed.

And we foresaw that in Congress. We thought we had addressed this geographic penalty, in part, through the authorization of NGI in 1998. But my sense is that it was not taken as seriously as it might be.

Today we are going to hear from two panels of experts. And let me apologize in advance. As I mentioned to our panelists, we are in the middle of a series of votes. And my colleagues are actually still on the floor voting. And when they call the next vote, I will likely suspend the hearing for a few minutes and run over and vote and come back. So I want to apologize in advance.

I am very excited about our two panels today. The first will consist of the President's Science Policy Advisor, Dr. Neal Lane, and other administration leaders, who will testify about ongoing research and development projects and programs being performed at their respective agencies. Also, I hope that we will look at some of the budgetary issues and highlight some of the new initiatives that the White House is undertaking this year.

The second panel will shift perspective, and we will hear from private industry pioneers, who will address some of the endless possibilities of the Internet and help paint the picture of the transformation that is associated with progress in Internet and Internet technology. We will also hear from two prominent university presidents, who offer a different view of the Next Generation Internet: how their institutions, their students and their faculties, in some ways, are being left behind.

So we have tremendous advances, tremendous inroads in the broad range of fields, yet we have one other area that I think has to be addressed in our panels and discussion today. And that is the digital divide. We are just simply leaving behind too many of our fellow Americans.

Internet II, which is a powerful consortium of over 150 universities and colleges, has a high, exorbitantly high, entry fee which simply precludes participation by both universities who will testify today. And I think that sends an important message to us as we address this issue of the digital divide. I have introduced legislation, with Senator Rockefeller and other colleagues, to address many of these geographical barriers.

I would also like to focus our hearing today on the President's new budget request for the NGI and large-scale networking programs. I hope the administration will be able to help the committee understand the nuances of these programs, despite what seems to be name changes each year. And, again, that is going to require both some talking today, and working with the committees and our staffs.

With that, let us go directly to our first panel. Let me simply say that I would like each witness to try to present his or her testimony in about 5 minutes. That means you will have to summarize your entire opening statements. Written opening statements will be made a part of the record. We will begin with the first panel. I will probably have to leave after Dr. Lane, but we will see what happens with this next vote.

Our first panelist, Dr. Neal Lane, is Assistant to the President for Science and Technology and Director of the Office of Science and Technology Policy. He is a familiar face in this particular room, and I want to thank him in advance for participating so actively, so aggressively in the overall development of science policy. He is followed by Dr. Rita Colwell, Director of the National Science Foundation; and Dr. Donald Lindberg, Director of the National Library of Medicine.

Let us begin with Dr. Lane, and we will proceed in that order. Dr. Lane, welcome.

[The prepared statement of Senator Frist follows:]

PREPARED STATEMENT OF HON. BILL FRIST, U.S. SENATOR FROM TENNESSEE

I would like to welcome all of our guests here today as the Subcommittee on Science, Technology, and Space convenes its first hearing of the millennium. It is rather appropriate I believe that the Next Generation Internet (NGI) should occupy this prestigious position. After all, the Internet is one of the most significant developments of the last decade. Its significance is not limited to the new industries that it has created, nor the new educational opportunities that it affords.

The impact of the Internet goes beyond those things. With the development of electronic commerce, the Internet has radically altered the economic landscape of this country. Advances in industries are taking place at a faster and faster pace. At the heart of this exponential rate of change are two things: computers and communications. More and more we are seeing that computers and communications means the Internet.

If you had to find a prototypical success story, it could very well be the Internet. There are in fact, multiple dimensions to its success. It was and is a successful public-private collaboration. It demonstrated successful commercial application of technology developed as part of federal mission-directed research program. It showed a successful transition of an operational system from the public to the private sector. Perhaps most of all, it is a prime example of a successful federal investment.

In some respects the Internet is now "suffering" from *too much* success. With the advent of tools that have made the Internet easy to use, there has been an explosion in the growth of network traffic. As computers become more powerful, applications more sophisticated, and the user interfaces become easier to use, we can look forward to an even greater demand for network bandwidth.

As we marvel about the revolutionary advances of the Internet and its ability to improve our daily lives, we often forget that the Internet is reaching its maximum potential because of the constraints on its speed, reliability, accessibility, and versatility. Therefore, now more than ever, we must look to the future and invest in the next generation Internet. If we want to experience the miraculous rewards of telemedicine and distance learning in our lifetime, we must, as a nation, continue to invest in research and develop advanced networking technologies.

Since the enactment of the original "Next Generation Internet Research Act", which I introduced in 1998, the National Science Foundation has connected over 170 universities and facilities to a testbed providing a 100-fold increase in network performance. And the Department of Defense is currenily deploying a testbed with 1000-fold increased performance at over twenty sites to support networking research and applications deployment. As we applaud the success of the first three years of the NGI initiative, we must also realize its current limitations.

In the review of the first two years of NGI, the President's Information Technology Advisory Committee recommended that the program should continue to focus on the utility of NGI's gigabit bandwidth to end-users, its increased security, and its expanded quality of service. More importantly, the committee shared Congress' concern that no federal program specifically addresses the geographical penalty issue—the imposition of costs on users of the Internet in rural or other locations that are disproportionately greater than the costs imposed on users in locations closer to high populations. I must admit that this is a great disappointment for myself and my colleagues who fought to combat this geographical penalty through the authorization of NGI in 1998. Unfortunately, the White House did not take us seriously.

We will hear today from two panels experts. The first will consist of the President's Science Policy Advisor, Dr. Neal Lane, and other administration leaders who will testify about the ongoing R&D projects and programs being performed at their respective agencies. They will also address budgetary issues and highlight new initiatives that the White House is undertaking this year.

Our second ranel will offer a different perspective. Two innovative private industry pioneers will address the endless possibilities of the Internet and its potential to transform and save lives. However, we will also hear from two prominent university presidents who offer a different view of the next generation Internet. Their institutions, their students, and their faculty are being left behind. While scientists throughout the country have made tremendous inroads during the past few decades, the digital divide makes the truth clear and simple: we are leaving many of our fellow Americans behind. Internet2, a powerful consortium of over 150 universities and colleges, charges an exorbitant entry fee which precludes participation from both universities that will testify before us today. I have introduced legislation with Senator Rockefeller and other colleagues to eliminate these geographical barriers.

I would like to focus our hearing today on the President's new budget request for the NGI and Large Scale Networking programs. I hope that the administration will he able to help the committee understand the nuances of these programs, despite the constant name changes from year to year. Thank you.

STATEMENT OF NEAL LANE, PH.D., ASSISTANT TO THE PRESIDENT FOR SCIENCE AND TECHNOLOGY, AND DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY POLICY

Dr. LANE. Thank you, Mr. Chairman and members of the subcommittee. I want to thank you for this opportunity to testify about the important research and development investments proposed by S. 2046, the Next Generation Internet 2000 Act.

These crucial investments would strengthen and expand research authorized, thanks to your sponsorship, by the NGI Act of 1998. The Administration has been heartened by the active bipartisan support for efforts to strengthen our Nation's investment in information technology research. Your leadership here in the Senate, Mr. Chairman and members of the subcommittee, has been instrumental in building support for Federal IT research, which promises to pay enormous dividends for the American people.

Today we live in an era of unprecedented promise and prosperity, built on advances in science and technology. Creative businesses have translated the results of federally funded advanced research into innovative products and services that enhance our daily lives. Nowhere is this more dramatically illustrated than in the IT sector. New computing, networking and communication tools allow Americans to shop, to do homework, to get health care advice online, and enable businesses of all sizes to successfully compete in the international economy.

More than a third of all U.S. economic growth over the past 5 years is attributable to this sector. Today, more than 13 million Americans hold IT-related jobs. Over 800,000 jobs were created by IT companies in the past year alone. Information technology is changing everything in ways we do not yet fully understand.

This remarkable progress has been built on a foundation of Federal research investments, leveraged by universities and industry. The President's Information Technology Advisory Committee, or PITAC, has emphasized that continued Federal investment is essential to maintain this momentum. We have heeded PITAC's recommendations in the President's fiscal year 2001 budget.

Our fiscal year 2001 budget presents a single, integrated information technology R&D portfolio, as recommended by PITAC, which includes the Base High Performance Computing and Communication programs, including Next Generation Internet, the new activities established by last year's Information Technology for the 21st Century Initiative, and the DOE's Accelerated Strategic Computer Initiative, or ASCI. The President is requesting $2.315 billion for IT research and development, 35 percent more than last year's appropriations.

Under NSF's leadership, the agencies will continue to support the following goals, based on PITAC's recommendations: improvements in software to enhance privacy and security of data, along with improvements in the ease of use; continued advances in high-speed computing and communications; and a better understanding of the social, economic and other impacts of IT, with emphasis on ensuring that all Americans will benefit from these technologies. The President's request for IT research and development addresses all of these goals.

Your NGI 2000 Act authorizes the large-scale networking component of our program, which represents about 13 percent of the President's overall fiscal year 2001 budget for information technology R&D. Your support, indicated in S. 2046, is a very important first step toward meeting our national needs for information technology research. Fast, reliable, ubiquitous networks provide the lifeblood for the 21st century economy.

Networking research is a core element of our Federal IT research portfolio. And the Administration welcomes your support for these important activities.

We feel strongly, however, that networking research must be conducted as an integral part of a program providing balanced investment in IT research, as well as research in social, legal and ethical issues raised by advances in information technology. This approach, which guided development of our interagency information technology R&D program, is consistent with PITAC's directive to strengthen our Federal information technology research programs by providing adequate funding for a complete and balanced IT research portfolio.

We were pleased to see the Committee address one of the Administration's priorities, the digital divide, in several sections of the bill. We are concerned, however, that specific set-asides provided for institutions in rural communities and minority serving institutions may not be the most efficient and effective way to provide greater opportunities for these institutions. We would like to work with you to ensure that existing mechanisms and programs are strengthened, to permit greater participation in federally funded IT research and access to the IT R&D resources.

Also, we note that the bill directs the National Academy of Sciences to conduct a digital divide study. The Administration believes that this requirement should be deleted, because it duplicates efforts already underway at the Department of Commerce.

Finally, the proposed legislation does not appear to authorize funding for the National Oceanic and Atmospheric Administration, NOAA, a long-time participant in the Federal IT programs and one of the agencies developing key NGI applications. We hope that the subcommittee will modify its proposal to authorize funding for NOAA, as outlined in the President's budget.

Mr. Chairman, as you know, our staffs have worked closely together during the initial drafting of your bill, and I am heartened to see the continued interactions our offices have on many issues of importance to the entire science and technology enterprise, and I thank you for that.

So, in conclusion, we thank you and the subcommittee for your continued support of IT research. The strong bipartisan support generated by these and complementary proposals allows us to invest in America's future and ensure its continued prosperity. We believe strongly that the President's proposal for a comprehensive IT R&D portfolio is essential to the Nation's prosperity and its ability to secure public benefits, ranging from national security to environmental protection.

And I look forward, Mr. Chairman, to working with the Committee on these issues in the weeks ahead. Thank you very much.

[The prepared statement of Dr. Lane follows:]

PREPARED STATEMENT OF NEAL LANE, PH.D., ASSISTANT TO THE PRESIDENT FOR SCIENCE AND TECHNOLOGY, AND DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY POLICY

Mr. Chairman and Members of the Subcommittee, thank you for this opportunity to testify about the important research and development investments proposed by S. 2046, the Next Generation Internet (NGI) 2000 Act. These investments are a vital portion of the Administration's information technology (IT) research portfolio that strengthens and expands the important Federal networking research authorized, thanks to your sponsorship, by the NGI Act of 1998.

The Administration has been very encouraged by the active bipartisan support which both chambers of Congress have provided for efforts to strengthen our nation's investments in information technology research and development and we look forward to continued support for the exciting new work proposed in the Administration's proposed FY2001 budget. Here in the Senate, your leadership, Mr. Chairman and that of the members of the Subcommittee, has been especially instrumental in helping your colleagues recognize that the advances in information technology which are so vital to the overall success of our nation's scientific and technical expertise, as well as to its economic prosperity, require a foundation of wise, sustained Federal research investments.

We are enjoying a time of unprecedented possibilities and prosperity, built on advances in science and technology enabled by Federal support for R&D. Creative businesses have translated the results of Federally funded advanced research into innovative products and services enjoyed today. This innovation has improved our quality of life, strengthened our national security, and unleashed an extraordinary era of post-war economic growth. Many of America's industries are now the most competitive and technologically advanced in the world. The Federal government has had an important role in sharpening our high-tech edge. Through policies such as investing in education, encouraging private-public partnerships, and limiting regulation of the Internet, the Administration has enhanced opportunities for scientific discovery and allowed innovation to flourish. Most importantly, as the President noted in his February 24 remarks to the Granoff Forum at the University of Pennsylvania, this Administration has worked to accelerate R&D at every level—pushing for an extension of the Research and Experimentation tax credit and increasing our national science and technology budget every single year over the last seven years.

The Nation Benefits from Federal IT R&D Investments

The case for sustained and adequate Federal investments in R&D is made most dramatically in the information technology sector. The President's Information Technology Advisory Committee (PITAC) notes that "that the technical advances that led to today's information tools, such as electronic computers and the Internet, began with Federal Government support of research in partnership with industry and universities. These innovations depended on patient investment in fundamental and applied research." The PITAC emphasizes, however, that continued Federal investment is essential to maintain this momentum. In their February 1999 report to the President, *Information Technology Research: Investing in Our Future,* the PITAC called for doubling Federal IT R&D investments over five years and expanding the existing coordinated interagency research programs to achieve a more balanced research portfolio. The Administration responded to the PITAC's proposals in FY 2000 with a major increase in IT research funding through the Information Technology for the Twenty-First Century initiative. We continue to build on the PITAC's recommendations with the programs recommended in the President's FY 2001 budget.

Although the dividends that our nation has reaped from past Federal investments in computing and communications research are well recorded, they are worth repeating. Federal support of IT R&D, leveraged by industry and academia, has led to technical advances which today are transforming our society and driving economic growth and the creation of new wealth. New computing, networking, and communications tools allow Americans to shop, do homework, and get health care advice online, and enable businesses of all sizes to join the international economy. Since 1995, more than a third of all U.S. economic growth has resulted from IT enterprises, and during the past decade, more than 40 percent of U.S. investment in new equipment has been in computing devices and information appliances. The IT sector is growing at double the rate of the overall economy and will soon account for 10% of the economy. Companies doing business on the Internet had an average market capitalization of $18 billion in 1999, more than 30 times the average market cap for all companies listed on the NASDAQ.

As computers, high-speed communication systems, and computer software become more powerful and more useful, IT penetrates deeper into our home, work, and education environments. Nearly half of all American households now use the Internet, with more than 700 new households being connected every hour. More than half of U.S. classrooms are connected to the Internet today, compared to less than three percent in 1993. In 1993, only a few technical organizations knew what an address like http://www.senate.gov meant, and today, there are nearly 13 million registered addresses. Today, more than 13 million Americans hold IT-related jobs, which are being added six times faster than the rate of overall job growth. Over 800,000 jobs were created by IT companies in the past year alone.

This astonishing progress has been built on a foundation of Federal agency investments in research conducted in universities, Federal research facilities, and partnerships with private firms. The Federal HPCC Program met its 1996 goals of demonstrating computers that perform a trillion operations per second and communication networks that transmit a billion bits per second. The Next Generation Internet initiative has exceeded its year 2000 goals by connecting more than 170 universities and other research centers at rates 100 times faster than those available when the project began and more than 15 institutions at rates 1,000 times faster. Such ultra-high-speed networks provide desktop-to-desktop connections nearly 20 million times faster than typical Internet connections to home computers.

The President's FY2001 IT R&D Budget

The President's FY 2001 budget reports all aspects of IT research—the base HPCC programs (including Next Generation Internet) and the new activities established by last year's Information Technology for the Twenty-First Century initiative—in a single integrated IT R&D program. The President is requesting $2.315 billion for IT R&D, $594 million more than last year's appropriations and a billion dollars more than the FY 1999 appropriation. The largest increases above FY 2000 funding are proposed for the National Science Foundation, which is leading the interagency effort (+$223M), the Department of Energy (+$150M), the Department of Defense (+$115M), the National Aeronautics and Space Administration (+$56M), and the Department of Health and Human Services (+$42M).

IT R&D Budget Summary

	FY 2000 ($M)	FY 2001 ($M)	Percent Increase
Department of Commerce	$36	$44	22
Department of Defense	282	397	41
Department of Energy	517	667	29
Environmental Protection Agency	4	4	0
Health and Human Services	$191	233	22
National Aeronautics and Space Administration	174	230	32
National Science Foundation	517	740	43
TOTAL	**$1,721**	**$2,315**	**35%**

Agencies will continue to support the basic goals established in last year's initiative, focusing on fundamental research in software; development of information systems that ensure privacy and security of data and allow people to get information they want, when they want it, in forms that are easy to use; support for continued advances in high-speed computing and communications, including work needed to ensure that raw speed translates into usable speed; and work to understand the social, economic, and other impacts of IT with emphasis on ensuring that all Americans will benefit from these technologies. The U.S. research community responded to last year's call for research ideas with a flood of creative new proposals, a demand which far exceeded the supply of new funding in agencies such as NSF and DOD. As a result, with FY 2000 funding, NSF will start 25 small research centers and five larger centers.

As in previous years, the proposed IT research portfolio is based on coordinated, interagency investments which leverage expertise across agencies to give the best returns on those investments, both financial and technical. FY 2001 IT R&D priority areas include:

Teams to Exploit Advances in Computing: Expanded activities by NSF, DOE, NIH, NASA, and NOAA will support new partnerships where information scientists, mathematicians, and experts in areas such as medical research, weather modeling, and astronomy can work together to build tools for solving the Nation's most pressing information problems. These partnerships will advance information science and lead to research breakthroughs in application areas.

Infrastructure for Advanced Computational Modeling and Simulation: In FY 2001, NSF plans to establish a second terascale (five trillion operations per second) computing facility to support the civilian research community.

Storing, Managing, and Preserving Data: Current networks and data storage systems are straining to support vast amounts of information. NASA's new earth observing satellite will generate data equivalent to three times the information in the Library of Congress every year. Research will include developing devices capable of storing a years output of such systems in devices the size of PC hard disks; searching data in a variety of formats including pictures, video, audio; and developing improved ways of filtering information, data mining, and tracking lineage and quality of information.

Managing and Ensuring the Security and Privacy of Information: Research will focus on systems that can ensure privacy and security without compromising speed and ease of use. DOE, for example, recently developed a prototype chip that can encrypt 6.7 billion bits per second. Work will accelerate in network protection and advanced encryption.

Ubiquitous Computing and Wireless Networks: This research will ensure that mobile and wireless systems can be integral parts of the Internet. These inventions will permit devices embedded in equipment, vehicles, portable or wearable devices such as medical monitoring equipment, and even kitchen appliances to identify themselves to networks automatically and operate with appropriate levels of privacy and security.

Intelligent Machines and Networks of Robots: Fundamental research in robots will help revolutionize our work and our lives—from earthmoving devices in hazardous environments to devices that fit inside blood vessels and help operating room surgeons to simple household robots. For example, NASA needs space probes that are smart, adaptable, curious, self-sufficient in unpredictable environments, and capable of operating in groups.

Future Generations of Computers: New paradigms will use advances in quantum computation and molecular and nano-electronics to devise radically faster computers to solve problems previously described as "uncomputable," such as full-scale simulations of our biosphere or surgical simulations. Viewing cells as computational devices will help enable the design of next generation computers that feature self organization, self repair, and adaptive characteristics that we see in biological systems.

More Reliable Software: Software bugs and glitches continue to shut down airports, delay product shipment dates, and crash 911 emergency systems. Methods to design and test software need to be as productive and predictable as tools used to design and test aircraft and bridges.

Broadband Optical Networks: DOD researchers have shown that optical networking can provide 1,000 times faster network backbone speeds. Improvements in optical switching and development of all-optical end-user access technologies will let users take full advantage of these speeds.

Educate and Train a New Generation of Researchers: New investments will fund more researchers, who are critical to increasing both IT research and teaching, and support major research centers. Programs such as the teams to exploit advances in computing will provide opportunities to educate and train a new generation of researchers whose skills cross-disciplinary boundaries.

Large Scale Networking (LSN) R&D

The research priorities addressing network capabilities fall under the Large Scale Networking (LSN) R&D component of the coordinated, interagency IT R&D programs. Our ability to fully capture the future benefits of IT depends on learning how to build and use large, complex, highly-reliable and secure systems. The President's FY2001 budget proposes $334 million for LSN R&D, which includes:

- the LSN base programs in traditional networking research to support agency mission requirements
- the Next Generation Internet (NGI) initiative, and
- research in Scalable Information Infrastructure (SII)

LSN base programs explore long range fundamental networking research issues and transition developing LSN products into tools to support agency missions. Continuing the Federally-supported R&D responsible for the core technologies that made the Internet and Internet applications possible, LSN focuses on technologies needed by the Federal agencies, infrastructure to support agency networking, and networking applications development.

Since its inception in 1998, the Next Generation Internet (NGI) initiative has been a primary focus of LSN, building on the LSN base programs to provide the networking research, testbeds, and applications needed to assure the scalability, reliability, and services required by the Internet over the next decade. The program has provided fast network testbed connections to 170 universities and other facilities, exceeding program goals for connecting 100 sites. It is now focused on two goals: providing revolutionary networking capable of operation a speeds a thousand times faster than typical systems operating when the program began, and providing key functionality for high speed networks including reliability, scalability, security, an ability to multicast, an ability to gracefully accommodate mobile wireless users and other users that may enter and leave the system, and other requirements of complex modern networks.

Scalable Information Infrastructure (SII) is the newest component of LSN. It was developed in response to PITAC recommendations for an expanded Federal role in networking R&D that includes interoperability and usability. The SII research goal is to develop tools and techniques that enable the Internet to grow (scale) while transparently supporting user demands. An integral part of LSN, SII R&D complements the LSN and NGI efforts. SII research will focus on deeply networked systems: anytime, anywhere connectivity; and network modeling and simulation.

The President's FY 2001 budget request by agency for the LSN component of IT R&D is as follows:

Agency	FY 2001 (millions)
Department of Commerce.	
National Institute of Standards & Technology	4.2
National Oceanic & Atmospheric Admin	2.7
Department of Defense	87.2
Department of Energy	32.0
Department of Health and Human Services.	
Agency for Healthcare Research and Quality	7.4
National Institutes of Health	65.6
National Aeronautics and Space Admin	19.5
National Science Foundation	111.2

* numbers may not add due to rounding

Next Generation Internet 2000 Act

The Administration believes that the support for the LSN component of the coordinated, interagency IT R&D programs indicated in S. 2046, the Next Generation Internet (NGI) 2000 Act is an important first step towards meeting our national needs for IT research. Fast, reliable, ubiquitous networks provide the lifeblood for a 21st century economy. They are essential for the conduct of business providing tools that can tie even the smallest businesses into international production and sales networks and let businesses of all sizes speed the rate they develop, test, produce, and market goods and services worldwide. Modern information networks are becoming essential elements of education and training, critical for providing safe air and highway transportation, and central for strategies aimed at boosting national productivity while minimizing the impact of economic activity on the natural environment. Fast, flexible, easily reconfigured networks are essential tools for our nation's military at peace, at war, and in the multiple peacekeeping and other tasks they are asked to provide. This is clearly a vital element of our national IT research portfolio, and the Administration welcomes the Subcommittee's support in gaining funding for this important research.

We feel strongly, however, that networking research must be conducted as an integral part of a program providing balanced investment in advanced software, high-end computing, high confidence systems, human-machine interface issues, and applications research which draw on innovations in both information science and research teams in areas such as advanced materials, climate and weather modeling, or astrophysics, as well as research into the social, legal, ethical and other issues raised by advances in information technology. This approach is consistent with the PITAC's directive to strengthen our Federal IT research programs by providing adequate funding for a complete and balanced IT research portfolio. We commend the Subcommittee for acknowledging in Section 3(1) of the bill the importance of supporting other IT research carried out by our Federal IT R&D programs. The language of the bill indicates, somewhat confusingly, that these activities should be authorized through the Next Generation Internet Program and the Large Scale Networking Program. However, the other elements of the Federal IT R&D program are complementary to, not subordinate to, the networking research authorized by the bill.

Networking research must be tied closely to research on the computers, the software, and the applications that drive them. Many of the most intractable problems in network research involve management of networks which may connect millions or even billions of nodes, providing high security and privacy at low cost in dollars or communication speed, and building systems which do not fail catastrophically when faced with component failures or hostile intrusion. All of these areas require close collaboration with researchers working software, the next generation of computers, and other parts of the information technology research program supported in our budget.

The President's FY2001 IT R&D budget presents all IT research, along with networking research, in a balanced R&D portfolio, as recommended by the PITAC. We hope that the Senate will support authorization for the entire range of information technology research as proposed by the President's budget and in accord with the PITAC's recommendations.

We were pleased to see the Committee's interest in providing the resources of information technologies to minority-serving institutions, rural communities and other underserved areas and groups. As you know, the Administration is seriously concerned about the nation's digital divide and its impact on the ability of these institutions to participate in our research enterprise. However, we believe that the bill is too prescriptive in providing resources for research on infrastructure for rural, minority and small colleges. Programs such as EPSCoR and the Minority Institutions Infrastructure already provide mechanisms through which these issues can be addressed. Also, starting with its new FY 2000 funding for IT R&D, the NSF has called on proposers to explore linkages with other institutions including HBCUs, Hispanic institutions, EPSCoR states and others to broaden the participation in the program. This strategy is used in many other ITR&D programs and links traditionally strong majority institutions with the strengths at HBCUs. We are concerned that specific set-asides provided through the legislation may not be the most efficient and productive way to provide greater opportunities for these institutions. We would like to work with the Committee to ensure that existing programs are strengthened to permit greater participation in Federally-funded IT research and access to IT R&D resources.

We note that section 7 of the bill directs the National Academy of Sciences to conduct a digital divide study. The Administration believes this requirement should be deleted from the bill because it duplicates efforts already underway at the Department of Commerce. Commerce's National Telecommunications and Information Administration published the first "digital divide" study in 1995. Its most recent study, "Falling Through the Net: Defining the Digital Divide" (July 1999), has become the leading source of critical information on Internet access and computer usage. The

NTIA study uses data collected by Commerce's Bureau of Census. The President's 2001 budget includes funding to permit NTIA to make this an annual study.

Many of the funding levels authorized by S. 2046, as introduced on February 9, are consistent with those proposed for the LSN R&D programs in the President's FY2001 budget. One exception is that the proposed legislation does not appear to authorize funding for the National Oceanic and Atmospheric Administration (NOAA). NOAA is a long-time participant in the Federal LSN programs, including the Global Ocean Interactive Network (GOIN) demonstration project in March 1999 which linked U.S. ocean researchers with partners in Japan. Using links supplied by NASA, DOD, and NSF, NOAA's Pacific Marine Environmental Laboratory (PMEL) demonstrated the first NOAA applications over the NGI, including Ocean Share, a collaborative environment for oceanographic research, and 3-D tools using VRML to demonstrate the evolution of El Nino, fisheries larval drift, and fur seal feeding trips. Further research will include exploring methods of using advanced networks for aggregating the vast quantities of data from NOAA's satellite and radar weather sensors and multicasting the data to the nation's research community for the development of improved weather forecasting, developing tools to enhance collaboration among atmospheric scientists and oceanographers over the NGI, and increasing the robustness, security, and flexibility of networks for environmental research. We hope that the Subcommittee will modify its proposal to authorize funding for NOAA, as outlined in the President's budget.

Finally, although it received separate authorization in the NGI Act of 1998, the work on the Next Generation Internet initiative has always been an integral part of ongoing work in the Large Scale Networking component of the coordinated, interagency IT R&D program. This year, as noted above, LSN includes not only the base programs and NGI, but also expanded research in Scalable Information Infrastructure research. It appears that all of these elements, which are combined in the LSN R&D portion of the overall IT R&D program we plan to undertake, are authorized by S.2046. The Administration clearly prefers that the Committee take a more comprehensive approach to authorizing IT research. While the Committee takes this suggestion under advisement, we would urge you to refer to the programs authorized by the current proposed legislation as Large Scale Networking, rather than by the name of one of the program subcomponents (NGI).

I hope that we can work with the Committee to make these modifications and resolve any other issues during the weeks ahead.

Conclusion

We thank the Subcommittee for its continued support of these vital research programs, first through the NGI Act of 1998 and now with the proposed NGI 2000 Act. These investments are an essential part of a larger, balanced portfolio of research developed according to the PITAC's directives for adequately funding our Federal IT research programs. The strong bipartisan support generated by these and complementary proposals allow us to invest in America's future and ensure its continued prosperity. We hope that we can work with the Committee to support the entire IT research portfolio proposed by the President. We believe strongly that this program provides a balanced program of research essential to the nation's prosperity and its ability to secure public benefits ranging from national security to environmental protection. I look forward to working with the Committee on these issues in the weeks ahead.

Senator FRIST. Thank you, Dr. Lane.

Dr. Colwell.

STATEMENT OF RITA R. COLWELL, PH.D., DIRECTOR, NATIONAL SCIENCE FOUNDATION

Dr. COLWELL. Chairman Frist and members of the Subcommittee, I thank you for inviting me to testify at this very important meeting. I welcome the opportunity to discuss how NSF has promoted excellence in computer and information science research and how we can all be confident that NSF's investments deliver a high return to the taxpayer.

I have prepared a written statement that I will submit for the record and I will be very brief in my summary.

Mr. Chairman, the Next Generation Internet program has been a tremendous success. The NGI has helped pushed the frontiers of computer and information science and engineering. It has allowed scientists and engineers across the country to do first-class, cutting-edge research. And the NGI has fostered the rapid transfer of research ideas to the private sector, helping to fuel the economic engine of the country.

But, I should point out, technology transfer is only part of the NGI's contribution. A broader and perhaps more important trend has been the transfer of people, trained in the most cutting-edge IT concepts, to the private sector. In a preliminary review of the NGI program, the President's Information Technology Advisory Committee, which we all refer to as PITAC, found that numerous NGI-funded scientists, engineers and students, who were first funded at universities, have gone on, in just a few short years, to found startup companies with an estimated market capitalization of about $27 billion.

Mr. Chairman, as my friend and colleague, Neal Lane, has just mentioned, the economic impact of IT investments has been enormous. The challenge now is to sustain this record of success. Last year, the PITAC concluded that Federal support for long-term research on information technology has been, in their words, "dangerously inadequate." This has led to the governmentwide initiative in Information Technology R&D, for which NSF is the lead agency.

NSF investments in high-speed networking research are an integral part of the IT R&D initiative. Mr. Chairman, the NGI program has been a great success in knowledge transfer, as I have mentioned.

We have also seen impressive gains in the geographic reach of high-speed connections. The NSF has had as its original goal under the NGI program to connect 100 universities, using the vBNS network. Today I am pleased to announce that over 170 connections, and the awards for these connections, have been made to U.S. universities. This includes over 40 universities in EPSCoR states, nearly one-quarter of the total. We have also taken steps to improve connectivity to Hispanic, Native American and historically black colleges and universities, through a 4-year, $6 million award to Educause.

Now just hooking up campuses to backbone networks is not enough to achieve true high-speed connectivity everywhere. New research problems have to be solved so that all of us can benefit. For example, achieving high performance from end user to end user, the so-called broadband last mile problem, remains difficult. Some commentators have remarked that the current network situation is a lot like having a four-lane highway, beginning the highway but not having the ending or leaving the ending with dirt roads. You cannot have the highways and then dirt roads.

Meeting this challenge and other related challenges, such as user authentication and verification, will be a major focus of future NSF networking efforts—what I guess we could refer to as the next Next Generation Internet.

Mr. Chairman, in marking the 50th anniversary of the National Science Foundation, we are celebrating vision and foresight. And I would remark that the recently retired hockey great Wayne

Gretsky used to say: I skate to where the puck is going, not where it has been. So, at NSF, we try to fund where the fields are going, not to where they have been. Our task is to recognize and nurture emerging fields and to support the work of those with the most insightful research. And we prepare future generations of scientific talent.

To conclude, Mr. Chairman, let me again thank you for holding this hearing so that we may exchange views on the future direction of this important area. Let me also restate the NSF's willingness to work with you and the entire Subcommittee to ensure a robust Federal IT investment, including the NGI program.

And we look forward especially to extending the Federal IT partnership to help ensure U.S. world leadership in information technology. Thank you.

[The prepared statement of Dr. Colwell follows:]

PREPARED STATEMENT OF RITA R. COLWELL, DIRECTOR, NATIONAL SCIENCE FOUNDATION

Mr. Chairman, members of the Subcommittee, thank you for allowing me the opportunity to testify on the National Science Foundation's role in fostering the next stages of the information revolution.

I am pleased to be here today. This is a topic of utmost importance for the future of our nation's economy and the well-being of our fellow citizens. A healthy, long-term federal investment in high speed networking and information technology overall is critical if the United States is to remain a world leader—not only in science and engineering—but in our economy, national security, health care, education and overall quality of life.

My prepared remarks today will include a short history of NSF's support for cutting edge concepts in high-speed networking and their transfer to the private sector along with a brief discussion of the following topics:

- NSF's participation in the multi-disciplinary Federal Information Technology Research and Development Initiative (IT R&D) for which NSF is the lead agency;
- NSF's participation in the Next Generation Internet Program—an integral component of the IT R&D initiative—our cooperation with private industry through the rich transfer of new ideas to the private sector, our cooperation with the other NGI agencies;
- NSF's efforts to promote connectivity and access for all, including our efforts to improve connectivity for rural and minority-serving institutions and our strong support for cutting-edge education activities designed to ensure that our citizens will have the scientific, mathematical, engineering, and technological expertise needed to excel in tomorrow's knowledge-based economy.

NSF Support for High-Speed Networking: A Record of Accomplishment

Mr. Chairman, this Subcommittee has long been a strong, bipartisan supporter of the federal investment in IT R&D. In the early 1980's, this Subcommittee strongly encouraged NSF to invest in high-performance computing resources for the nation's academic scientists and engineers. The subcommittee also was a leader in the enactment of the High Performance Computing Act of 1991. This leadership continued with the passage of the bipartisan Next Generation Internet Act of 1998.

With this backing from the Subcommittee and the entire Congress, NSF has continued to support some of the most successful and innovative computer-communications concepts and technologies at their earliest, most experimental stages. NSF funded university-based supercomputer centers in the mid-1980's to provide academic scientists and engineers with access to state-of-the-art computing power.

To facilitate access to the centers, NSF began a parallel effort in networking. It built on fundamental investments by DARPA in a more restricted environment, and resulted in the formation of the national NSFNET backbone network and regional networks connecting university students and faculty to the supercomputing centers. In a very brief period of time, NSFNET and the regional networks began performing important communication and information access functions in addition to supercomputer center access. Through this development and its subsequent privatization, the Internet industry was born.

Mr. Chairman, the story of NSF's longstanding support for backbone networks is now well known but it is only one example of how fundamental IT investments by NSF and other agencies have paid huge dividends for the nation. Support of fundamental networking *research* has received less publicity but is equally important to the future of information science and technology.

For example, it was David Mills, an NSF grantee at the University of Delaware, who made it possible to have one Internet as opposed to a Tower of Babel of competing electronic networks. Mills developed the first widely-used Internet routers—the gateways and switches that guide the bits and bytes of data around the globe at the speed of light. That's why many people say NSF put the "inter" in Internet. Today CISCO Systems—the premier maker of Internet router technology—now has a market capitalization of $454 *billion* dollars.

Knowledge Transfer Not Just Technology Transfer

Innovations like the Internet router only occurred through sustained, long-term federal investments in information science and engineering by many agencies. One might think that these past successes assure us of an equally bright future. Unfortunately, in a fast paced, technologically-rooted information age, the worst thing we could do is rest on our laurels.

The key point is that the IT R&D conducted by private industry—be it performed by large or small firms—is now primarily near-term and product-focused. There are many reasons for this trend. With increased global competition, increasingly rapid product cycling and high expectations from shareholders, IT industry managers tend to focus on activities that maximize short-term payoffs. Market pressures are often too great and technology changes too rapid to allow for major investments with a long-term perspective.

When the subject of technology transfer is brought up, there is one aspect of the impact of basic research that is often overlooked—the role of NSF's investments in people. NSF's Engineering Directorate recently sponsored a set of studies on today's leading technologies: areas like cell phones, fiber optics, and computer assisted design. It's well known that the great majority of the seminal work in these areas was performed by private industry—at labs like Corning, AT&T, and Motorola.

Does that mean that NSF had no role? Hardly. When you go back and look at the work, a clear pattern emerges. Scientists and engineers who went to graduate school on NSF fellowships and research assistantships often brought the key insights to industry. In a number of cases, they became the entrepreneurs who created new firms and markets.

To quote from the study—"NSF emerges consistently as a major—often the major, source of support for education and training of the Ph.D. scientists and engineers who went on to make major contributions...." It is this transfer of people—the highly trained scientists and engineers supported by NSF and other agencies—that is making a tremendous impact on our knowledge-based economy.

The NGI program is a tremendous success in this regard. In a preliminary review of the NGI program, the President's Information Technology Advisory Committee (PITAC) found that numerous NGI-funded scientists, engineers and students—first funded at universities—have gone on in just a few short years to found start-up companies with an estimated market capitalization of over $27 billion.

Information Technology Research (ITR)

The impact of information technology on our society has been much wider and much more pervasive than anyone could have anticipated just a few years ago. Advances in computing, communications, and the collection, digitization and processing of information have altered the everyday lives of all our citizens.

There is no question that as Internet growth has gone through the roof, IT has become the essential fuel for the nation's economic engine. Even the ever-cautious Fed Chairman Alan Greenspan has pointed to innovations in IT as the driving force behind our strong economic growth.

The numbers speak for themselves. As Neal Lane has mentioned, more than a third of our economic growth in the past five years has resulted from Information Technology. IT investments have spurred an enormous upswing in worker productivity that has fueled the current economic boom. The challenge now is to sustain this record of success.

Last year, the PITAC concluded that federal support for long-term research on information technology has been "dangerously inadequate." In its words "support in most critical areas has been flat or declining for nearly a decade, while the importance of IT to our economy has increased dramatically." This has led to the government-wide initiative in Information Technology R&D for which NSF is the lead agency.

The Information Technology Research Initiative at NSF will emphasize research and education on a broad range of topics. Focus areas include:

• ***Advancing computer system architecture***; research on software, hardware, system architectures, operating systems, programming languages, communication networks, as well as systems that acquire, store, process, transmit, and display information.
• ***Improving information storage and retrieval***; research on how we can best use the vast amount of information that has been digitized and stored.
• ***Connectivity and access for all***; research that aims to overcome the digital divide separating the information "haves" from the "have-nots" and research on inequality of access to and use of computing and communications technology.
• ***Scalable Networks of Embedded Systems***; As the scale of integration of systems that may be achieved continues to grow, systems must be designed with both hardware and software aspects treated from a unified point of view.
• ***Novel approaches***; new models of computation and physical processes such as molecular, DNA and quantum computing. These efforts are deeply anchored in the mathematical and physical sciences and the biosciences.

Through our part of the multiagency IT R&D program, the InformationTechnology Research (ITR) initiative, NSF will seek to strengthen **Education** in IT, including:

- programs that provide scholarships, fellowships and traineeships;
- improved undergraduate research participation;
- encouragement of graduate students to participate in K-12 education; and develop new curriculum; and
- research aimed at understanding the causes of underrepresentation of various segments of society in the workforce.

NSF will also increase research on **Applications** of IT across fields of science and engineering. This will also be a critical component of the ITR initiative. This includes simulation to tackle research problems across the frontiers of science and engineering. Important networking applications include:

- Collaboration Technologies
- Digital Libraries
- Distributed Computing
- Remote Operations and
- Security and Privacy issues

Finally through the ITR Initiative, NSF will increase it's support for **Infrastructure** including the Next Generation Internet Program. Support for infrastructure will include:

- computing facilities ranging from single workstations to clusters of workstations to supercomputers of various sizes and capabilities;
- large databases and digital libraries, the broadband networking, data mining and database tools for accessing them;
- appropriate bandwidth connectivity to facilitate interactive communication and collaboration and software to enable easy and efficient utilization of networked resources; and
- networks of large and small physical devices.

NGI Connections at NSF: A Tremendous Success

Mr. Chairman, the NGI program has been a great success. Enabled by fundamental advances in optical networking under supported by DARPA and NSF, the number of very high performance networks has increased and the available bandwidth for research and education has had phenomenal growth.

A diverse array of US universities in all 50 states now have high-speed connectivity thanks to NGI investments. In fact, many more institutions than originally anticipated now have high-speed access thanks to the program. Connectivity to Alaska and Hawaii has improved dramatically as well.

NSF's original goal under the NGI program was to connect 100 universities using the vBNS network and the Internet2 Coalition's Abilene network. Today NSF is excited that over 170 university connection awards have now been made. This includes over 40 universities in ESPCoR states—nearly one-quarter of the total.

This increase in connectivity has resulted in interest in high performance networking in both academia and industry. It has had enormous impact on the knowledge transfer I mentioned earlier. Having so many more scientists, engineers and students from across the nation involved in high-speed networking activities has dramatically increased the available talent pool for industry.

Universities form a rich, fertile proving ground for new network ideas and concepts that can be quickly transferred to the private sector. Without consistent federal funding, such a well-spring of ideas could run dry.

What's Next for NGI: The Next-Next Generation Internet

In marking our 50th anniversary, we are celebrating vision and foresight. The recently retired hockey-great, Wayne Gretzky, used to say, "I skate to where the puck is going, not to where it's been."

Mr. Chairman, at NSF, we try to fund where the fields are going, not to where they've been. We have a strong record across all fields of science and engineering for choosing to fund insightful proposals and visionary investigators.

It is our job to keep all fields of science and engineering focused on the furthest frontier. Our task is to recognize and nurture emerging fields, and to support the work of those with the most insightful reach. And, we prepare future generations of scientific talent.

In this tradition, NSF is looking at new directions for the NGI program. One trend is clear: high-speed fiber backbone networks are rich seed beds for new capabilities.

Now that connectivity has been dramatically increased, new fundamental research problems must be tackled. In today's networked world, dramatic increases in backbone speed do not automatically translate into dramatic increases in performance. Many of these problems will not be easily solved without new, novel approaches.

Today, achieving high performance from end user to end user—the so called Broadband Last Mile Problem—remains difficult. Some commentators have remarked that the current situation is like having a four-lane highways beginning and ending with dirt roads.

To increase backbone speed, efficiency and stability, we will need fundamental research into new middleware network service capabilities. This includes research in user authentication and verification, distributed computing services, and distributed storage services. Also, NSF will support research dealing with satellite and other wireless technology to help reach into areas where wireline and fiber are not possible or practical.

We will also need research into new optical access technologies. In the future optical backbones will use more and more optical routing. Research is needed to discover how to appropriately extend the reach of these technologies. This will correspondingly extend the reach of networks and ensure that institutions not now taking advantage of high performance networking have the opportunity to do so.

Bridging the Digital Divide

This brings me to my last point. Today we find ourselves on a precipice—looking down into that worrisome gap known as the digital divide. We are all here today because we believe in the power of information technology to bring about the most democratic revolution in literacy and numeracy the world has ever known.

We also know that if we're not careful, this same power could be economically divisive. We imagine universal connectedness, with talk of "tetherless networks" that anyone could tap into anytime, anywhere.

But we could also broaden the gap between the information rich and the information bereft. In our own nation, sociologists have identified groups whose access to telephones, computers, and the Internet lag far behind the national averages.

These information gaps appear among nations as well. Most of those who live in the Third World have never used a telephone. Our worldwide web is a thinly stretched one. Less than two percent of the world is actually on the web. If we subtract the United States and Canada, it's less than one percent.

The report by the President's Information Technology Advisory Committee (PITAC) spells out some of these gaps. "For instance," says the committee, "whites are more likely than African-Americans to have Internet access" at home or work. "We expect there are similar gaps with other minority groups, such as Hispanics and Native Americans. Recent research...suggests that the racial gap in Internet use is increasing."

In September 1999 NSF made a four-year $6 million award to EDUCAUSE to help minority-serving institutions develop campus infrastructure and national connections. The award addresses Hispanic, Native American, and Historically Black Colleges and Universities. The scope includes:

- Executive awareness, vision, and planning
- Remote technical support centers
- Local network planning

- Local consulting and training
- Satellite/wireless pilot projects
- New network technologies: Prototype installations
- Grid applications

Conclusion

To conclude Mr. Chairman, let me again thank you for holding this hearing so that we may exchange views on the future direction of this important area. Let me also restate NSF's willingness to work with you, the subcommittee and the full committee to ensure a robust federal IT investment including the NGI program. The PITAC report has raised important concerns over our lack of federal investment in fundamental IT research and we at NSF are responding to the challenge. We look forward to extending the federal IT partnership to help ensure U.S. world leadership in IT.

Thank you.

Senator FRIST. Thank you, Dr. Colwell.

Dr. Lindberg, welcome. And you can remind everybody who the first physician was to use the National Library of Medicine Internet base.

Dr. LINDBERG. I might just do that.

Senator FRIST. Dr. Lindberg, you are welcome. It seems like yesterday, by the way, although many things have occurred since then.

STATEMENT OF DONALD A.B. LINDBERG, M.D., DIRECTOR, NATIONAL LIBRARY OF MEDICINE

Dr. LINDBERG. Thank you, Mr. Chairman. Like Dr. Colwell, I have a full statement for the record, and I will make a very much abbreviated set of remarks if you will permit.

The Next Generation Internet and large-scale networking project that you are considering is extremely important and will be helpful to the country. I think it should be viewed as a continuation of the High-Performance Computing and Communications program that began in 1991 in legislation, and 1992 in action, and extended up through 1997, as well as of course the Internet today, which shows much of its success because of the HPCC program.

I have a bias, because I was asked to be the first head of the National Coordination Office of the HPCC program as it operated under OSTP. And I did so from 1991 to 1995 very happily. Consequently, I have a profound respect for the goodness of the scientific collaboration one can obtain from members of the other Federal agencies and the importance of pulling together when the effort is warranted by a major national need.

The Internet today has certainly helped and changed the National Library of Medicine. And as you noted, you presided, at a very signal moment; namely, on April 16, 1996, when you did the first public search of MEDLINE on the World Wide Web.

Senator FRIST. And better yet, I searched for my name, and we found some articles there, scientific articles.

[Laughter.]

Dr. LINDBERG. They were good ones.

As a matter of fact, at that time, we were doing roughly 7 million searches a year of MEDLINE. And that event started an escalation of use that really has been quite remarkable. We are now up to 250 million searches per year on that same data base, which, as I say, you first inaugurated.

We are really not surprised, in a way, because MEDLINE is essential for the conduct of modern science and the conduct of modern health care when one is after up-to-date scientific and medical information. We were surprised, however, that about a third of these MEDLINE searches now are conducted by the public, by patients, families and friends. That is to say, non-doctors, non-medical scientists.

Because of this surprising event, we created a new data base, called MEDLINEplus, which is aimed directly at the public. And this is now off and running, a rather good success. I can give you more information about that if you wish.

We added to this complex just yesterday morning a data base called Clinicaltrials.gov, which gives detailed information on behalf of the 4,000 clinical trials that NIH either conducts or supports in 47,000 locations.

Because not every household in the U.S. has a personal computer and a World Wide Web connection, we started studies a couple of years ago with 39 public library systems to try to discover if help could be found for those who would otherwise be forgotten. This has been a helpful program, and it has given us the basis for a new set of outreach grants, some 49 in number, which are meant to encourage partnerships between medical libraries, which really are still pretty key in this field, and community, especially rural, organizations. The latter include public libraries, churches, elder care institutions, and really all those who will encourage the spread of electronic health information to the public.

I might insert that I wholeheartedly agree with you that we cannot forget to get Internet everywhere, or Next Generation Internet, everywhere in the country where it is needed, including the last mile or yard or inch.

I should mention that one other part of the National Library of Medicine which has benefited greatly from the improving network system. This is the National Center for Biotechnology Information, where Genbank and the results of the Humane Genome Project come to reside. They are very much dependent upon Next Generation Internet for their ultimate success.

As you know, the real product of the Human Genome Project, this worldwide distributed experiment, is information. There is only one human genome, we believe. The information all comes to reside at NCBI, that is to say NLM. It is exchanged daily between the U.S., Europe and Asia. There are now 5 million DNA sequences, made up of 5 billion nucleotide-based pairs. A sort of amazingly symmetrical set of numbers.

All this would be wholly unthinkable without high-speed and reliable network connections. Again, I could comment more about the details of that matter.

I should mention specifically support by the National Library of Medicine of NGI biomedical developments. This really started in 1992, with our request for biomedical participation in the High-Performance Computing and Communication program. We originally couched this request in terms of the areas that had been cited in the guideline legislation.

I will not recite those six categories. But we actually found, to our surprise, that by far the more scientifically meritorious proposals all fell in the area of telemedicine. Consequently, our next request for solicitations in 1995 focused on telemedicine. And these awards were, scientifically and medically, extremely interesting. In fact, to this day, they continue to yield important insights both in medicine and communications technology.

In 1998, NLM requested phase I NGI proposals along the same lines. In this case, of course, the proposals for NGI were somewhat different, because the NGI program speaks of technology that does not exist at the moment and has applications in areas that would not be possible without the new technology. Consequently, there are new challenges for medical institutions to participate.

That was the reason we made the awards bi-phasic. Nonetheless, we awarded about two dozen phase I awards, and then a reduced number of larger phase II awards for the most successful ones. I am prepared to go through these and describe these in detail, but I think for the moment you might allow me just to mention a few examples of the types: privacy of computers based on patient records, tele-immersion teaching of surgical anatomy, nomadic computing as practiced by ambulances and helicopters, tele-mammography networks, multi-center clinical trials, telemedicine with nursing homes, and radiation treatment planning. These are examples.

The lessons learned so far, in my view, are pretty straightforward. First, there are increasingly numerous interesting and useful biomedical applications in these advanced networks. In other words, it is a very useful field. And, second, biomedical applications do seem to be different from the rest and require more than just speed. I will give you four things that are examples of what is more than just speed.

Firstly, quality of service is probably much more important for the health applications than any other single element. Second, medical data privacy. Without that, we are never going to get day-to-day useful ordinary applications. Security, in the sense that every other system needs it. We do not want to be destroyed by hackers. And then, fourthly, an element which is called nomadic computing. It sounds a little strange, but it fits the wandering style of the physician who moves from clinic to clinic and floor to floor and hospital to hospital.

Also, as it turns out, one of our awards meets the wandering style of the young mother, who is a working mother and trying to keep in contact with the pediatrician and the child and the drug store and all the other things that modern life is beset by. So nomadic computing turns out to be a pretty solid specification.

Now, we need to translate all this into proper engineering and physics. Bits per second, packet length, jitter, latency, these kind of figures. These do not have much meaning medically yet. So our objective is to translate that so that we know what medical procedures and decisionmaking require for that level of communication. That is really the major task.

There is another side of it, I must say, I find equally interesting; namely, what kind of practice can be enabled by this work. Is teledermatology a very good application? It seems like it. Is home health care going to be a radically new departure? Can we improve the quality of care and reduce the errors in decisionmaking? I think all those are quite possible.

So, in a way, I am prepared to give examples, but I think, in truth, the best is yet to come. Every week we see really good new applications of biomedical uses of the Next Generation Internet. And I heartily endorse your help to that program.

Thank you for the opportunity to be here.

[The prepared statement of Dr. Lindberg follows:]

PREPARED STATEMENT OF DONALD A.B. LINDBERG, M.D., DIRECTOR, NATIONAL LIBRARY OF MEDICINE

Mr. Chairman and Members of the Subcommittee:

It is a pleasure to report to you on the role of the National Library of Medicine in helping the health sciences prepare to use the capabilities of the Next Generation Internet for the betterment of the public health. You may recall that from 1991 to 1995 I had a dual appointment as both NLM Director and head of the OSTP Coordination Office for High Performance Computing and Communications. This was a major interagency program that included 14 departments and agencies. At that time the Internet was still "terra incognita" to most of the medical community, and I was pleased to be able to help establish a medical component in the HPCC arena.

Much has changed in the past few years, and, Mr. Chairman, as you may recall, you played an important role in that evolution. On April 16, 1996, you conducted the first public search of our database, MEDLINE, on the World Wide Web. Since that time, MEDLINE usage has soared from 7 million searches a year to a current rate of 250 million. Health professionals and scientists, of course, see Web-based MEDLINE searching as a great asset in their research and clinical care. They can now easily find out what their colleagues are publishing by searching an up-to-date database of more than 10 million scientific journal article references and abstracts. What amazed us, however, was to discover that MEDLINE is also being used by the general public. We estimate that about 34 percent of all MEDLINE searches are done by the public—for information about their own health and that of family members and friends.

We realize that not everyone has direct access to the Internet and can take advantage of MEDLINE or our new consumer health site, MEDLINE*plus.* To help remedy this, last month the Library made 49 "outreach" (attached) awards to medical libraries around the country. The aim is to help them to work with local public libraries, schools, senior centers, and other community organizations to help bring the benefits of electronic health information to those who otherwise would be forgotten. I believe that all of us, not just those concerned specifically with the Next Generation Internet, should seek ways to ensure that *all* Americans have access to the information they need to keep themselves healthy.

To ensure that the Internet will continue to support the health sciences, the NLM is a strong supporter of the Next Generation Internet effort. To help create a sound theoretical underpinning for medicine and the NGI, we have sponsored a number of research projects in universities and hospitals and also studies by the Institute of Medicine (on Telemedicine) and the Computer Science and Telecommunication Board (on Data Privacy). All conclude that health care and biomedicine place important demands on the capabilities of the future Internet in such areas as quality of service, medical data privacy, and system security.

These elements are important considerations in many of the testbed applications the Library has supported over the last several years. Spread out over three phases, the NLM will support more than $45 million in NGI projects. These include telemedicine-related projects, advanced medical imaging, and patient-controlled personal medical records systems. These projects have given rise to a new nomenclature, for example, tele-immersion, tele-presence, tele-trauma, tele-mammography, tele-psychiatry, internetworking, and nomadic computing. Spanning the generations, from at-risk infants in Boston to home-bound seniors in Missouri, this research seeks to improve quality, lower costs, and increase effectiveness for delivering health care. We hope the projects will lead to new applications based on the ability to gather information at a distance and to transfer massive amounts of data instantaneously and accurately while maintaining medical data privacy. In the last phase of our support, in FY 2001, there will be a set of meetings to record "lessons learned" from this work and also a scale-up of selected promising projects to regional or national level.

Advanced medical imaging is a special category that requires more bandwidth than is currently available on the Internet. The extremely large size of NLM's Visible Human image datasets challenges existing storage and network transmission technologies. A full set of the images—both electronic and photographic—would require the capacity of more than 100 CD-ROMs. Since this is obviously impractical, we are investigating advanced compression and networking techniques to minimize storage capacity and improve transmission speed over the Internet. The need for such techniques is even greater when we consider that we are currently working with other NIH Institutes and the National Science Foundation to create a super-detailed head and neck anatomical atlas. We will also include appropriate image manipulation tools for use via the Internet, based on open software conventions.

Another area of medical science that requires increased communication capabilities is human genome research. As you may know, the NLM's National Center for Biotechnology Information (NCBI) maintains the enormous GenBank database of molecular sequences. It now contains some 5 million nucleotide sequences with a total of nearly 5 billion base pairs, and the Web site where GenBank is made freely available, receives some 800,000 queries per day from 120,000 scientists and others around the world. In addition to academic institutions, major biotechnology and pharmaceutical firms are among the heaviest users of the NCBI Web site. They not only search GenBank, but use NCBI-created computational tools such as that which allows researchers to use the growing body of known 3-dimensional structures to infer approximate 3D sequence structure from similarity relationships.

In summary, Mr. Chairman, the need for the capabilities of the Next Generation Internet is apparent to us who work in biomedicine. Its increased bandwidth and expected Quality of Service provision will allow the transmission of complex images in real time for diagnostic purposes, which is not currently possible. Using the Internet to coordinate the gathering and dissemination of information required for conducting extensive multi-site clinical trials is yet another example of a medical application beyond the present capability of the network. Other applications require a guaranteed level of service (for example no data loss, or assured privacy protection) that today's Internet cannot provide. There are many others that I have not mentioned, such as home healthcare, continuing medical education, public understanding of science, or even reduction of errors in medical practice. Actually, the very best applications have not yet been developed! Each week brings even better and more imaginative biomedical uses of networks. I'm confident the final result will be a major improvement in American health care.

Senator FRIST. Thank you, Dr. Lindberg.

I thank all three of you for your outstanding testimony. And I have had the opportunity to read your testimony.

As an aside, it is interesting every time the students come in you realize, as we are listening to this testimony and you see those students over there, the world that this work has opened up, whether it is addressing the fundamental infrastructure or the applications or the digital divide, the implications that it has for their future. So as we sit up here, watching them come in and out, it makes you realize how important both the work that you do is and our investment and our addressing the problems that are introduced by the advances that are made. It is fascinating.

Dr. Lindberg, it is fascinating, in your opening statement, when we did that in 1996, in terms of access, World Wide Web, Internet-based information, the figure that you cited, not just the growth in access of information, but the public's access of one out of three of those searches of MEDLINE being the public. At the time, I would not have predicted it. We would have predicted some. And I remember even that day that we talked a little bit about when you let this information out, what happens.

How do you reflect upon that? Now we have 3–4 years of experience with it. Before that time, probably one in 20 searches, I am guessing, would have been by a non-medical person and now it is one in three.

Dr. LINDBERG. I think it would probably be less than 1 percent.

Senator FRIST. And then today, what are the implications today? Obviously people have that. We talk about costs. We talk about quality. We talk about empowering consumers. We talk about intelligent consumers. We talk about preventive medicine. Is there any way you can—it is all of those things—but where you can see all of those queries coming in? How would you summarize it?

Dr. LINDBERG. Well, I think there is a new factor loose in health care, and that is the activated patient, long ignored. We hear frequently now of patients who will consult the medical literature even before they consult their physician. And rather than shy away from this, I welcome it. I think this is probably an informed patient who is increasing his or her likelihood of getting a good benefit when they do see the doctor or they go to the hospital.

This clinical trials database that we just announced yesterday is a wonderful thing. It means that anyone who is not satisfied with the treatment they are offered—I mean who can be satisfied if they tell you there is no treatment and you are going to die? Anyone with any sense is either going to find another doctor or another information source or something. That is not hard to imagine—you can now at least find out what the Federal Government, through NIH, is paying for. And in years to come, we will add those trials conducted by the drug houses and perhaps even internationally.

So I think that this is an era in which we just have to acknowledge that the patients of today are very different from 40 years ago. They are better educated. They are more sophisticated. They are more ready to be partners in the decisions about their own care and in fact their own steps to remain healthy. I think it is a wonderful development.

Senator FRIST. It is impressive, in 3 and a half years, the changes that are there.

I want to turn to Senator Rockefeller. But, Dr. Lane, let me just mention—and I appreciate the directness of your testimony and the comments that were made and the suggestions—I will have to state that there is some confusion to me, reading through the testimony and looking at the numbers, how funding for the interagency program is structured. Which means that I need to spend more time, and maybe our staffs can get together and spend more time in the near future, to better understand the overall funding structure.

And it would also be helpful to me if your office could prepare a more detailed list of the funding components within each of the participating agencies, including the amount of funding requested for each of the individual programs. And we do not need to go through it now, but that would be very helpful. It would help me understand and share with other members on this subcommittee.

Dr. LANE. We will provide all that, Mr. Chairman.*

Senator FRIST. Let me ask just one question. If the President's Information Technology Advisory Committee called for a doubling of Federal information technology R&D over a 5-year period and an expansion of the interagency research programs to achieve a more balanced portfolio—the President's 2001 budget requests a 35-percent increase over the preceding year, which, if maintained, would

* Information was not available at press time.

mean a doubling in just over 2 years—could you explain that observation, this rapid doubling, at least, or rapid curve, shooting up this year, which would be more than a doubling versus what the initial recommendation was?

Dr. LANE. Mr. Chairman, first, the Information Technology Advisory Committee did a very careful job of giving their best sense of how these increased investments ought to go. But I also think they would agree that their anticipation was that we would then bring the agencies together and look in some more detail of what we are doing and what are reasonable numbers on a year-by-year basis. And that has been done.

And the President's budget request last year—and we only got two-thirds of that through the appropriation process, so we started a little behind where we thought we ought to be, and so this year, we catch up a bit in that regard—but puts us pretty well on the doubling track, I think. But the thing I would want to emphasize is that it also reflects our deeper analysis of what is possible and how fast we need to make progress in these important areas and the very high priority the President and Vice President put on this area.

Senator FRIST. On the balanced portfolio, could you give examples? Or how is it more balanced now than it has been in the past?

Dr. LANE. I think part of the confusion that probably many have with the different names that are associated with the programs comes from the fact that in the original High-Performance Computing and Communication Act, there was an important networking component that was called large-scale networking. And we have used that same name to try to capture the program as it evolves. And all that has really happened is that the technology has moved so rapidly and the opportunities and the challenges changed so rapidly that, understandably, there are new components of the program that come along.

So, in 1998, the NGI effort put an emphasis on more attention to networking research, but also test beds, because the need was there and the opportunity was there. And then, finally, in the President's fiscal year 2001 budget, as a result of the PITAC report—actually, fiscal year 2000 and then continuing this year—is this thing called scalable information infrastructure. It is just an evolutionary track toward a higher level of complexity, higher bandwidth, an increasing need to address some of these fundamental problems such as my colleagues have spoken to.

So we believe it is a unified program. And we also emphasize that networking should not stand on its own. It must couple to high-end computing. It must couple to social behavior, and economic issues. It must couple to other aspects of the President's overall program. Because these interrelate and they depend on one another. And we look forward to working with you to better articulate how all this fits together.

Senator FRIST. Thank you very much.

Senator Rockefeller.

STATEMENT OF HON. JOHN D. ROCKEFELLER IV, U.S. SENATOR FROM WEST VIRGINIA

Senator ROCKEFELLER. Thank you, Mr. Chairman. I had one of the worst scheduling days of my life and I totally apologize to you and particularly to the panel and the panel that succeeds it.

I had a meeting recently in which a very small company came in and described how they were going to provide an infrastructure for a high-speed network, which would cover half the country. I had known them as a very, very small company, but they had plans to become a big company very quickly.

I was trying to think, on the one hand, you have the ability of a company to make those plans. Now, whether they can raise the money for it and do it, that's another thing—but if they raise the money for it, they will do it. And it is all laid out. They have figured out how they can do it and beat others to market in some very smart ways. It was a very fascinating hour or so.

So, you have that sort of infrastructure at the very large level that is privately initiated. If they can get across LATA—and they can—they can build this new network.

My daughter is on the board of trustees at Spelman. Spelman College, as you know, is a terrific African-American women's college. The college has decided, on a small scale, that the best way for African-American women to advance in this society is to excel in the fields of math and science.

So they are making an institutional commitment to change their curricula to reflect that. Which, I have to assume, has wrenching effects on all kinds of faculty and students who are there, majoring in teaching or other subjects that they think are really important and, to some extent, or altogether, may be getting pushed aside for a new institutional thrust. That is the broad idea, which has consequences on all of us.

How does this bill, which I proudly cosponsored with Senator Frist and others, address the information infrastructure for the next generation? In a way, a new infrastructure is difficult to build, as my two examples illustrate. Can we control this new infrastructure since the ground rules for some of the relevant technologies were laid out in the Telecommunications Deregulation Act?

Dr. Lane, would you comment first?

Dr. LANE. I will make a quick comment, but I certainly want you to have a chance to hear from my colleagues on this issue. I will say a couple of things, Senator. First of all, it is great to see you today, and I really appreciate the opportunity to be here.

Many of the quite extraordinary advances that are going on, what companies are doing, what regions are doing, institutions are doing, are stunning, I think, by any measure. Every time I hear one of these stories, I am impressed with the vision and the commitment. The recognition that information technology is changing everything about how we live and how we learn and how we do business and how we ensure the public's health and well-being.

But when you look sort of one level down and start to ask questions of a company or an institution about what it is they plan to do and what kind of barriers do they see they face—it may be there are cost barriers or there are other kinds of barriers—then all of these issues that have come up in the PITAC report and in some of the testimony here start to come forward.

There are things like privacy and security—and of course we know about security problems from our recent experiences in this country—and speed and end-to-end high bandwidth. We have very impressive progress being made all over the country on the speed at which we are able to communicate across the backbone, but we cannot deliver, for the most part, anything like that same speed to the room, to the desk, whether it is in the classroom or in our home or anyplace else.

There are some fundamental questions about, do you go to an all-optical system, and how do you design the optical switches that you will need? Because, right now, we waste a lot of our time converting from optics, photons, to electrons, and we have to get past that. And there are many, many, many technological barriers in the way.

These are very fundamental questions. And they are the kinds of things that industry really cannot afford to address. They do not have time. They have got to get out there and compete in an increasingly competitive market. And they are very dependent on the Federal Government to make those investments, those long-range investments, in those fundamental challenging problems that we need answers to so that the next next generation of computation and communication will be ours to enjoy.

Senator ROCKEFELLER. Can I expand the question, Dr. Colwell, so you can answer it, too? Because, in a way, it is philosophical. Exactly as you say, the network will be all optical. They are going to do the whole thing. It sounds improbable maybe, but it was very impressive.

And then, this new book by Michael Lewis, they use the word impose—I think Jim Clark used the word—we are going to impose technology on the American people. I think that was exactly the quote. We are going to impose the technology on the American people. So the next question is, how do we account for social responsibility when we "impose" this new technology?

Now, into our Next Generation Internet bill is built 10 percent for ESPCoR, and that does certain things. But social responsibility is a very large bandwidth in this country. And do we face up to any of that?

Dr. COLWELL. Well, I am very pleased with the connections program that the NSF has run. And that is to make sure that the connections to rural areas and to the underserved are made. And we pledged—and this is a program Neal Lane started—I am very happy to say that we had pledged to make 100 of these awards and we were able to make 170. And 40 of these were to ESPCoR institutions.

I would like to comment about your earlier statement, because I think it is very important. We make the connections across academia and all the states, but we can say that the tracks are laid and the companies are providing the high-speed connectivity, but we have a lot of research yet to do. For example, we are creating a billion-node Internet, but we really cannot simulate a million-node network. And so we have some fundamental breakthroughs that we have to make in many disciplines, not just in computer science, but in mathematics, physics, chemistry, social and behavioral sciences, in order to ensure a stable and a well-connected Internet.

And so the issues that Neal Lane raised—end-to-end user connectivity, scalability, but also middleware software—are important. We do not have an operating system for the Internet. And so this is important for us to develop. Companies can make the connections and provide the high speed, but there is an awful lot to be done before we are there.

Dr. LANE. May I just add a comment to that?

Senator ROCKEFELLER. Please.

Dr. LANE. I shudder when you quote someone as saying we are going to impose technology on the American people, because I worry that the American people feel that, indeed, that does happen to them all the time. And I want to make clear that the President and the Vice President, whenever they talk about technology, and information technology in particular, emphasize to me or in public comments the importance of sitting down with the American people and considering what they want and what their values are.

That if we just plow forward with imposing technology on the people, first of all, we may get pushed back. Second, we are likely to miss the very things that the American people need and want. And, the third thing, it is just wrong, from my point of view.

So I want to emphasize that, in the President's budget request and coming out of PITAC's recommendations, we have a strong emphasis on social and economic issues associated with information technology, doing whatever it takes to support research to help us understand what are the implications of these important technologies on people's lives. And NSF plays a very important role in that activity.

That is a new piece of technology. And you will also see it in the President's nano-technology initiative. There will be attention given to social, behavioral, economic, work force aspects. And I think we should do it for every kind of technology initiative that we have.

Somebody ought to ask the question, as you did, Senator, to what extent does this address the values of the American people? And we think that is a very important question, and we will respond to it.

Senator ROCKEFELLER. Dr. Lane, I think you have answered the question in exactly the right way. But it struck me that the President could not help holding out what is possible in science and none of us can help it. When the President was giving his state of the Union, he was talking about the little, tiny machines which could clean out your arteries and do all kinds of things. That is what is so fascinating—the possibilities.

Those possibilities of science are what this bill address—creating the next generation internet, making sure that we are keeping up with others. I am not sure that we are keeping up, and I want to ask about that: do we have time, between this generation of the Internet and the next generation, to do what has to be done?

But philosophically, at the bottom, the people—and it is not just people in Silicon Valley, which that book was written about, but people everywhere—do not have time, because of competition. I mean theirs is so much more brutal a competition. By the way, I have told the airlines they have got to stop telling us that every nickel makes a difference, because the new economies could wipe them out. Now, every penny makes a difference, and that is all they have time to think about.

So the question is what are the effects of new technologies on all of us, as the American people. We can say we have got to distribute resources in a balanced manner so we will do ESPCoR. We will make sure the next generation internet gets into this or that community, and we will hope there are more Spelman Colleges.

But, in the end, we are not in control. It seems to me—and I want to put this as a question, not as a statement—that the forces of innovation are always going to overrun, the forces of the corrections necessary to make the innovation broadly or fairly applicable. As a U.S. Senator, I have to worry about that fair application, coming from the state that I do. So I wonder if you could just respond to this idea—the out-of-scale proportion of the power of innovation versus the power of the rest of us to try to equal things out.

Dr. LANE. Senator, we believe in a free market system in America, and it has always had associated with it these kinds of tensions, I guess, and conflicts. And often we have serious problems associated with that.

I think that is what we call leadership. If you look at the President's speech to the Cal Tech faculty, when he went out and sort of rolled out the science and technology initiative—so there the President is speaking to the scientists, the researchers, and he is emphasizing how important it is to pay attention to American values—not just in thinking about what kind of research to do or how to feel about the new technologies, but in the whole process of doing it and to encourage further engagement—I mean real dialog, if you like, with the American people.

The second thing I would say is that we have a window of time—I do not know how long it is—in information technology where it is still evolving, where we are still figuring out where it is going and how to use it. It is getting cheaper for its capability, in per bit, or per bit per second or per computation. There is a time here when we could, if we give proper attention to the issues you are raising, we could use this technology, we can ensure that this technology really does start to close the gap. We call it the digital gap; it is more complicated than a digital divide or a gap, but that is the idea.

And I think if we look back at this time and discover that we did not pay attention to what might just be an enormous opportunity with this technology to address some of these issues that we have been grappling with for decade upon decade, we will have not done our job. So I appreciate the emphasis you place on this. And yes, I do agree and want you to continue to worry about these issues.

Senator ROCKEFELLER. Dr. Colwell.

Dr. COLWELL. I would like to say it also provides a very strong argument for continuing the investment to ensure connectivity. We can, through virtual centers, connect scientists in every part of the country. We can connect citizens to the opportunities that would not otherwise be possible.

And I think we have seen this through, for example, the partnerships that we have provided in advanced computing. This reaches out to every part of the country, and so it does not leave anybody out. And that is the power of it. And that is why we really have to keep the investment going. And the timing is critical.

Senator ROCKEFELLER. Well, my final question would be, do we do enough in this bill? Are there things that you think that we are deficient on?

Dr. COLWELL. Well, I would not say deficient, but I do think that there are some things that we do need to pay attention to. And that is scalability. It is a key recommendation from PITAC—modelling and simulation of network behavior, the issue of the billion-node network, but we are not even able to simulate a million-node network. So there are some fundamental breakthroughs that are needed.

And I think the applications across all of science and engineering really need to be a priority. But, Neal, I think you wanted to say something else.

Dr. LANE. I would add, just to repeat a comment I made earlier, that the networking part of the information infrastructure program for the Federal Government is now built into a larger information technology R&D program. It is well-coordinated. It connects where it makes sense to connect. It is coordinated among agencies where you want agencies to work together. And so it is a little bit artificial to separate the networking part, Internet, away from high-performance computing, high-end computing, social, behavioral, ethical, economic considerations.

So we think this is a great first start. There are some small issues having to do with—I think NOAA is not currently mentioned in the bill, and they are a very important agency here, and there are a few issues like that—but we think it is an important first start. We would like to see the whole program authorized. We would like to see the whole Federal effort in information technology R&D authorized and the appropriate connections made between the different parts.

Senator ROCKEFELLER. And, Mr. Chairman, before I continue my outrageous behavior and walk out on you entirely, let me emphasize again that I understand that we could spend all of our time trying to make each and every person totally equal in access by March 29th, and it will not happen. Innovation is sacred unto its own core value and to the American ethos, as you indicated, Dr. Lane.

And we can also hold ourselves up by putting up barriers. And I am not talking about sort of Internet taxation or some of the more conventional types of things, but perhaps sort of the social reaction against innovation, which could be very damaging to all of us for the very hurts that lie inside of me potentially as I look at states like my own. And that is why I am on the bill.

I have only a desire to see this drive forward with the assumption that all of you and us working together, and the American people, are going to have to try very, very hard to make the whole thing as fair as possible. But an alternative cannot be to say, oh, well, we have got to slow down this until we can catch up on this. And I understand that.

Dr. LANE. Thank you, Senator. If I might just add one thing. I think we have to do things in parallel with our R&D effort. And the President's digital divide program that he has brought forward with the fiscal year 2001 budget lays out a number of other things that we can do in addition to R&D to address shorter-term needs, tax advantages, tax incentives, for companies to work with the community. It is all in the spirit of partnership.

Senator ROCKEFELLER. And I understand that. But it is like every time I hear one of those on my side of the aisle talking about 100,000 new teachers, when I know perfectly well we need 2.5 million. I feel good, but I also know that it sounds good to say 100,000 new teachers, but you are not really addressing the problem.

Dr. LANE. We can always do more, sir.

Senator ROCKEFELLER. And we do not have to agree on that publicly.

Senator FRIST. I agree.

[Laughter.]

Senator FRIST. Let me ask a couple of questions, and then we will move on to our second panel.

Senator Rockefeller, before you leave, under my tab, following Dr. Lindberg's testimony, there are a series of projects in here. It says projects funded by the National Library of Medicine, January 2000. That is always very dangerous to present this in a complete document. And Alabama looks good and Arizona looks good. Arkansas looks good. California looks good, Connecticut, the District of Columbia.

The only two states that do not have these grants in there, Dr. Lindberg, are West Virginia and Tennessee. Remember that in your next funding from the National Library of Medicine. Because Tennessee is not in there, nor is West Virginia. We have got to be in there.

Senator ROCKEFELLER. And to get to the Tri-cities of Tennessee from West Virginia is only about an hour and a half drive by car. So this is a ferocious task that Dr. Lindberg has in front of him.

Senator FRIST. We will put the charge out there.

Dr. LINDBERG. Well, I was going to comment that when I last saw Senator Rockefeller, we were putting our Smartcards into a reader connected to the computer in West Virginia. And my pseudo practitioner card let me, combined with his pseudo patient card, let me read his medical record and find out he had been immunized against tetanus or something like that. And I think West Virginia is a pioneer in this. I'm glad NLM supported this network.

The use of Smartcard technology, very extensive in Europe, very minor in the U.S., I think is an example of the counter-argument that we have not even begun to do good coordination of the information technology and the health care technology. I think that is a very good experiment. That is what lets you certify you are the patient and you are the doctor and the access is authorized.

Senator FRIST. Extending that a little bit, you mentioned in your testimony, on telemedicine itself, we are not quite there. And it is very useful to hear about the progress that has been made, but also put out there what it is going to take to capture that next step in terms of telemedicine. Is there going to be an incremental jump, do you think, in the next couple of years in terms of telemedicine, the cost of that?

Dr. LINDBERG. I do. I think that one of the very important areas is what is sometimes now called home health care. And this fits very well with the development of wearable computers and computers that can continue to take pulse and blood pressure and temperature and so forth. So that, to a great extent, you can really do a physical examination at home right now.

Senator FRIST. That is tremendously exciting.

Dr. LINDBERG. Yes, Senator.

Senator FRIST. Dr. Colwell, let me jump real quickly, just because the second panel, I know we should move to the second panel here shortly. Both university presidents have submitted testimonies basically saying that the NSF has a bias toward the Internet II universities. What is your agency doing to ensure that all of the hundreds of universities around the country are not left behind just because they are not a part of the Internet II consortium?

Dr. COLWELL. I mentioned the connectivity program. That is specifically to augment grants for high-performance network connections, to defray the costs, for rural institutions and for the non-research institutions. And so, through this program, we have made a substantial number of awards. And 40 of these have gone specifically to the ESPCoR institutions in ESPCoR states.

In our latest funding request that has gone out, we are making a concerted effort to ensure that we do connect, go the last mile to connect every one of the institutions throughout the country. We are making a concerted effort. This is part of our specific task for the next year.

Senator FRIST. Thank you. We will keep the record open for further questions. Dr. Lane, in terms of the categories and line items, I very much want our staffs to get together so it will be clear for me.

Dr. LANE. I look forward to it.

Senator FRIST. Let me thank all three of you. There are many different questions, many different topics. It is always frustrating when there are so many topics that we could talk about, but we appreciate your taking time and investing it with us today. Thank you.

We will go straight to the second panel at this juncture. I would ask that they come forward.

Dr. Thomas Carter Meredith, Chancellor of the University of Alabama System; Dr. Bill Stacy, Chancellor of the University of Tennessee Chattanooga; and Mr. Stephen Tolbert, President and CEO of Global Systems & Strategies.

As I mentioned in my opening statement, the focus will shift, as we look at some of the end users, the implications of our current policy today. Let us go in that order. I will begin with Dr. Meredith, followed by Dr. Stacy and then Mr. Tolbert.

STATEMENT OF THOMAS CARTER MEREDITH, ED.D., CHANCELLOR, THE UNIVERSITY OF ALABAMA SYSTEM

Dr. MEREDITH. Thank you, Senator Frist. And thank you for the opportunity to be here today to talk about the critical importance of an advanced telecommunications infrastructure for higher education, and especially to research universities.

I have a longstanding commitment to the deployment and use of information technology in higher education, as evidenced here in my 9 years as a campus president and now in my current role as the Chancellor of a system of three doctoral research institutions, the University of Alabama at Tuscaloosa, the University of Alabama at Birmingham, and the University of Alabama at Huntsville. We have combined our own resources and NSF grants to develop joint access to Internet II through the creation of the Gulf Central Gigapop. "Joint" is the key word, as our three very competitive universities are increasingly holding hands now on major projects to assist our state and our Nation.

I am here on behalf of the states participating in ESPCoR, the Experimental Program to Stimulate Competitive Research. A number of members of this subcommittee represent ESPCoR states, and we appreciate their past and continuing support for our efforts. As you know, ESPCoR focuses on the 19 states and Puerto Rico, which historically have received the least amount of Federal R&D funding from the National Science Foundation, the National Institutes of Health, and other Federal programs.

ESPCoR members represent approximately 16 percent of the U.S. population, and receive only about 8 percent of the NSF research budget, and about 5 percent from NIH. ESPCoR states have relatively large rural populations, and many have research strengths based in agriculture and natural resources, which were the traditional economic keystones of their states. A number have special under-represented groups to assist, as well.

And while agriculture and natural resources remain significant parts of our economy, we are experiencing business and industrial expansions in other areas. Our institutions are attracting faculty who are conducting research in disciplines requiring access to global resources, access that will depend on participation in the Next Generation Internet.

We know we are educating our students for a new economy based more on information, knowledge and business skills than in the past. And we know that our states' economies and our citizens' and students' standard of living are increasingly tied to a global economy.

There are nationally and internationally recognized research programs emerging in the ESPCoR states, including several NSF engineering research centers. And in my own state, the University of Alabama Medical Center in Birmingham is recognized as one of the finest medical centers in the country.

Access to the Internet and, specifically, to the Next Generation Internet, is crucial to these programs and to the overall economic and educational development in the ESPCoR states. Let me zero in on the issue at hand: the Next Generation Internet authorization legislation.

Thanks to efforts in this subcommittee, and through the help of George Strong, the ESPCoR office, and others in NSF, ESPCoR institutions have been able to participate in the Next Generation Internet despite early indications that it might be limited to only 50 or 100 institutions. We faced the real possibility of being shut out of perhaps the major infrastructure initiative of this decade.

And it goes without saying that this would have severely crippled our research capabilities.

However, we did obtain at least one high-speed connection for each ESPCoR state. And we did have representatives from our states included on several committees and panels. And we are included in several NSF initiatives. However, the job is not finished. ESPCoR states continue to struggle with connection costs and with the development of scientific applications of the advanced networking systems. I believe we have the people; our need is infrastructure and support.

The rural infrastructure and the minority and small college Internet access initiatives are also of particular importance to the ESPCoR states, where cost of Internet access remains a significant barrier, as you mentioned earlier.

Let me close with two points. One is the importance of providing an assurance that the ESPCoR states will continue to be included in the Next Generation Internet program. This is essential to our being competitive for funding from NSF and other agencies. We may have a brilliant faculty member with a truly outstanding proposal. But if we do not have the connectivity and the infrastructure, that faculty member is disadvantaged in grant competition and therefore research capability.

Second, we ask you to work with us. I have had experience in three ESPCoR states now—Mississippi, Kentucky, and Alabama. All three have real research success stories, developed in the settings where we teach, work, conduct our research, and interact with our communities and states. Help us with resources. Help us by including us in the relevant committees, panels and boards. Help us in finding collaborations. We can make important contributions to the development of Internet technology, infrastructure and applications.

There is a real danger of a higher education digital divide, that has been discussed today, that could leave institutions in many states, particularly rural states, out of the Next Generation Internet. The importance of this issue to research, student education, business, and economic development is underscored by its prominence at the National Governors conference which just concluded here. During that conference, Alabama Governor Don Siegleman announced plans to call together leaders from across our state to address how Alabama can meet the technology challenges of the 21st century. There is a commitment there.

I believe the bill before you puts us on the right track to prevent a digital divide in higher education. And I appreciate your efforts, and I thank you for allowing me to be here today. Thank you.

Senator FRIST. Thank you, Dr. Meredith.

Dr. Stacy.

STATEMENT OF BILL STACY, PH.D., CHANCELLOR, THE UNIVERSITY OF TENNESSEE AT CHATTANOOGA

Dr. STACY. Thank you, Senator Frist.

I appreciate very much the commitment to the policy considerations that you and your subcommittee and your colleagues in the U.S. Senate pay to science, to technology and to space. The wise investments of you and your colleagues and the U.S. Senate, particularly your 1998 bill, have propelled efforts to create and to claim the incredible assets of technology and science that extend the reach and the power of the human mind. Your investments to motivate America's brightest intellects to pursue the potential of the Next Generation Internet and large-scale networking programs serve this Nation's highest ambitions and, indeed, its highest obligations.

NGI, Internet2, large-scale networking programs, such as Abilene and the very High Backbone Net services, push back the frontiers of knowledge, and offer computational sophistication that many of us thought unbelievable just decades ago. Such intellectual tools provide hope for medical research, the Nation's security, for environmental preservation, for business/industrial modelling. In short, the potential of the NGI extends and builds on what causes any of us to marvel at what is reported at any scientific journal this month and, indeed, in every daily newspaper this week.

Federal funding of the NGI encourages and enables our best brains, whether in universities, research corporations or foundations, to pursue those discoveries whose applications seem destined to outpace even today's e-medicine, e-commerce, e-data management, I suppose even e-politics, whatever those e's are that are revolutionizing the intellectual, economic and social lives of Americans.

My brief comments accompany a better statement which I prepared and have delivered to your committee. And it talks of the challenges of a metropolitan university who claims as its only reason for being its response to the areas, clusters, that it serves. Joining me for an indication of the excitement of research at the University of Tennessee, is President Wade Gilley. He has just joined us and has signalled a dramatic recommitment to research for the land grant flagship university at Knoxville. Dr. Duane McKay has recently accepted appointment as the Vice President for Research and Technology of our University System.

My remarks focus on the value of the NGI and the request that this committee consider broadening access. The country cannot allow "haves and have-nots." Maybe we are beyond that, but probably we ought not allow "have and have-mores" either. I think Senator Rockefeller was trying to get a handle on that in his comments a moment ago. In university parlance, we talk about breadth and depth. And I think it is time perhaps that we could broaden access to the sophistication of combinatorics and other possibilities this Internet will allow us.

Fast Internet is the key to so many things. It is surely our national goal. With limited resources as you began, it was proper I think to focus it. But now, as you see developing value, I just think it is enormous and maybe we could share some of the access and entry points.

A major disconnect occurs with faculty, with universities, with businesses, with communities, where that territorial absence of that cluster of sophistication exists. There are whole regions omitted from the high-speed networks. You know that if you put some sort of a map of the Internet II over Internet I, it looks remarkably similar.

Sure, it is Boston and it is New York to Philadelphia, and it is Pittsburgh and it is Chicago and it is Atlanta, and it is a little in St. Louis, and it is Florida and all the national labs, and it is Boulder and it is the West Coast, and you see it in, San Diego, Los Angeles, San Francisco, Seattle. And then you look at lots of areas of this country where that cluster of sophisticated technology is absent. So I would say to you that, as part of a system at the University of Tennessee, our campus I think will not be a part of the developing of the sophisticated protocols that many of the Carnegie I research doctoral universities will provide.

Nonetheless, the absence of access for any faculty, for any business, in a community where there is a great deal of research potential, for the Tennessee Valley Authority, looking at electric power, at water, at resources, great insurance corporations headquartered in our area, logistics, looking at water—there are many areas where access to the computational potential that would be involved would make a tremendous difference.

Our sister institution at Knoxville, the flagship university, in its Carnegie I status, has been able to make that connection to the performance network. And the connectivity has been able then to generate other access and other grant opportunities, a great deal of sophisticated research, both in this country and in cooperation around the world.

You have seen a number of those things. It is wonderful to see the early harvest Internet application initiative, providing that privacy, authentication, authorization, to support medical applications. And you have seen the University of Tennessee College of Veterinary Medicine, having the live animal clinic caseload, sharing with colleges of veterinary medicine throughout the Southeast.

You have seen the Radiology Department of the University of Tennessee's Health Care in Memphis involved in a program to monitor and direct ultrasound studies throughout the region. And so there are many opportunities in telemedicine, medical research, distance education, lots of ideas. Indeed, in the Architecture School, using some on-demand live and archived digital video, to help us in the teaching and the research of architecture.

To just summarize, I think my comments are these three. The country and the world are well-served by that wise investment begun by this country over the years. And it is highlighted by your 1998 Act. And what you are now considering is pursuing the assets of this next generation of Internet II. Higher education joins you in making this a very high priority in the intellectual lives of the Nation's campuses throughout the country.

While the work of discovery and protocol for the Next Generation Internet remains critical to understanding, applications are already beginning. America's genius of the free market has entrepreneurs seeking to rush the applications to Americans even before the ink is dry on the last discovery.

And third, the request that I bring to you is for broadened access. We need to be sure that the NGI is accessible to any faculty member, any person bright enough, competent enough to contribute to its development or its application. Pricing now allows only about 25 of the 700 universities in the South to be members—

25 of 700. Across the country, you heard 150, maybe 170, of nearly 4,000 colleges have that connection.

The strategy perhaps could allow campuses or systems some way to distribute access through the flagship campus. Current membership fees currently disenfranchise campuses that could compete on their own merit for applied research and development in a secondary applications.

The reality of this Republic is that its best resource is always its people. The genius of America lives and works in every state and region of this country. We are a mobile population, to be sure, but we cannot all live in Silicon Valley. We need to have the ability to make intellectual opportunities and capacity more readily available to more people in more places. The competitive nature of freedom to think, to create, to apply inevitably works for the advantage of all Americans.

Thank you very much for what you are doing for this country.

[The prepared statement of Dr. Stacy follows:]

PREPARED STATEMENT OF BILL STACY, PH.D., CHANCELLOR, THE UNIVERSITY OF TENNESSEE AT CHATTANOOGA

Since its founding in 1886, The University of Tennessee at Chattanooga has been dedicated to providing quality education to a diverse population of over 8,600 students, focusing on the development of excellence in undergraduate education and in selected areas of graduate study. We increasingly strive to provide the best public undergraduate education in Tennessee. Our goal is to assist the economic development and to improve the quality of life for Tennessee and the surrounding region through expansion of its intellectual capital.

The University of Tennessee at Chattanooga's professional and graduate programs are better able to serve our students through the unique assets of the metropolitan, living laboratory of Chattanooga and surrounding metropolitan clusters. The University of Tennessee at Chattanooga has developed into an excellent Master's Comprehensive I Carnegie institution and is now evolving into distinction as a comprehensive public metropolitan university. The campus "accepts its relationships to the surrounding metropolitan region as its essential rationale, its reason for being," in the words of Daniel Johnson and David Bell in their treatise on this emerging model of higher education institutions.

The purpose of my testimony today is to relate the experiences of The University of Tennessee at Chattanooga in the Next Generation Internet environment, and the challenges we face to achieve full participation in that environment. We are completely aware of the impact high performance networking will have on how we conduct our instructional and research activities in the 21st century, and that some of those activities will undergo profound change. As in the case of many non-Research I institutions, however, The University of Tennessee at Chattanooga does not currently have equitable access to NGI funding, and to the national and regional high performance networking infrastructure, and, thus, is not benefiting from the rich opportunities for collaboration, innovative instructional delivery and resource sharing that the NGI allows. While one goal of the NGI and Internet2 initiatives is to extend the fruits of advanced networking to all levels of educational use, this is far from being a reality today. As documented in the 1999 EDUCAUSE report *Advanced Networking for All of Higher Education:* "It was noted during a meeting among affiliate members of the Internet2 project late in 1997 that consideration of how the products of these leading edge efforts might 'diffuse' to the broader higher education community—and how to prepare for it-was lacking."

In the absence of a strategy for diffusion, institutions like The University of Tennessee at Chattanooga may have to be content with waiting for the eventual "trickle-down," while most likely having to tolerate the consequences of being on the wrong side of the "digital divide" and the impact that will have on our status and competitiveness. Such a scenario is intolerable to us, and, thus, we are appealing for your consideration of the strategic funding and support that will be necessary to reduce inequities in the NGI environment before those inequities become unassailable.

Simply stated, The University of Tennessee at Chattanooga does not have the financial resources necessary to support campus involvement in NGI/Internet2. In fact, of the more than 700 four-year and two-year universities and colleges in the nine-state Southeastern University Research Association network (including Alabama, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, and Tennessee) who are eligible for participation in the NGI/Internet2, only 25 institutions are currently members. These numbers clearly show that campuses like The University of Tennessee at Chattanooga have overwhelmingly chosen not to participate. Since the benefits of participation are readily evident, one can assume that non-participation results from prohibitive factors.

For The University of Tennessee at Chattanooga to gain its own access to Internet2/Abilene, membership fees, connector fees, participant fees, and other charges are estimated at $277,000 for the first year with equal recurring charges in subsequent years. At a time of extremely tight state funding and with the commitment to hold student fees to levels that do not limit accessibility, such costs, even for crucial expenditures, are beyond the reach of most campuses.

Significant problems face campuses that are unable to participate in the NGI/Internet2. As The University of Tennessee at Chattanooga recruits Ph.D.-qualified faculty members, access to networks such as NGI and Internet2 is becoming increasingly important. As doctoral candidates, these faculty members took advantage of the opportunities afforded them by these networks, and their research efforts depend on continued use. The inability of institutions like The University of Tennessee at Chattanooga to provide this high speed access will either deter candidates from joining their faculties or for those who accept positions, their research will be stifled. Similarly, faculty members whose research interests develop on campuses lacking network access may choose to leave for positions where access is available. In either case, the result is a loss of well-qualified faculty members for campuses who lack the resources to maintain network connections.

The University of Tennessee at Chattanooga has increased its emphasis on research, especially applied research that addresses the issues and needs of a metropolitan region. Applied research has more relevance in the educational environment as students can readily see knowledge "applied" to solving real problems. Likewise, applied research increases the opportunities for partnerships between the campus and the community. Grant funding for NGI/Internet2 projects does not appear to favor applied research efforts.

Curriculum development and the implementation of new degree programs, especially graduate and doctoral programs, is affected by the lack of access to NGI/Internet2. Student and faculty research will increasingly become dependent—in some fields the need is already absolute—on access to high speed network connections, and campuses that do not have connections will be unable to recruit faculty and students in those disciplines, effectively disabling the program development.

The current fee structure is certainly a deterrent to participation for campuses such as The University of Tennessee at Chattanooga where, at present, perhaps no more than 10 faculty embers are engaged in research which could require use of high speed access to computational capabilities. This discounts the possibility of significant research accomplishments by small teams or individuals at regional institutions and instills a bias in the system toward large institutions where a greater number of users would result in high demand for bandwidth.

Despite lack of involvement in high speed access projects, The University of Tennessee at Chattanooga has made great technological strides, especially in its on-campus fiber network. In terms of campus network infrastructure, The University of Tennessee at Chattanooga meets the standard requirement of delivering at least 100 Mbps to the desktop for on-campus traffic; this surpasses the capabilities of many NGI/Internet2 participating campuses.

We may lack the external network connection to access NGI/Internet2, but The University of Tennessee at Chattanooga does not lack vision and desire for participation. If The University of Tennessee at Chattanooga had access to the NGI/Internet2, the types of research activities which might be advanced include the design of mechanical prostheses, gait analysis, and computational physics, engineering, and chemistry. One faculty member in mathematics studies acoustic models and uses algorithms to detect objects in shallow water. Both the military and oil industry have expressed interest in this research, which is threatened if he does not gain high speed connection. A major insurance company with its headquarters in Chattanooga has worked with a business faculty member to explore new financial models for stock market predictions. Environmental modeling could include the tracking of pollution in the Tennessee River through partnerships in a water quality research center which includes the Tennessee Valley Authority, the Tennessee Aquarium, and the University of Tennessee at Chattanooga. Chattanooga has received international attention for its successful efforts in air and water pollution control and interest in environmental research is significant both on The University of Tennessee at Chattanooga campus and in the community.

The direct public benefit from expanded access to the NGI for campuses like the University of Tennessee at Chattanooga would be the quicker response to identified needs through applied research results. In a recent address, U.S. Congressman Zach Wamp tied the development of additional graduate and doctoral programs at The University of Tennessee at Chattanooga with the economic vitality and future of Chattanooga and the surrounding area. Jim Kennedy, president of the Chattanooga Area Chamber of Commerce echoes Wamp's sentiment. "Chattanooga is a city that has reinvented itself," said Kennedy, "and we are in the midst of a strategic planning process—the success of which will hinge in large part on The University of Tennessee at Chattanooga's ability to deliver on applied research. Moreover, the change in technical training required of college graduates underscores the need for a well-wired university."

In comparison to The University of Tennessee at Chattanooga's experiences, I would like to illustrate what NGI participation and federal support can enable by describing the experiences of The University of Tennessee, the flagship institution of The University of Tennessee System in Knoxville. I hope my illustration will demonstrate what the NGI is enabling now in some reaches of higher education, and what the NGI will enable in future, once the challenges to full exploitation of NGI resources are overcome. Most significantly, I hope this illustration will serve to elucidate what benefits institutions like The University of Tennessee at Chattanooga are being deprived of in our current exclusion from the NGI.

A charter member of Internet2, The University of Tennessee was the recipient in 1997 of an NSF High Performance Connections grant ($350k) to fund connection to the very High Performance Backbone Network Services (vBNS) national backbone. Since February 1999, UT has accessed the vBNS via the regional GigaPOP at The Georgia Institute of Technology in Atlanta with a 45Mbps. (DS-3) connection, and has also connected to the regional Southeastern Universities Research Association network, Southern Crossroads, via the GIT GigaPOP.

Currently, both the Knoxville and Memphis University of Tennessee sites are preparing to migrate to Abilene, the Internet2 gigabit backbone. With the relaxation of the Abilene conditions-of-use in 1999, primary Abilene participants are now in a position to sponsor secondary participants, once meritorious use is demonstrated. Organizations, such as libraries, museums, K12, and institutions such as The University of Tennessee at Chattanooga, who would not otherwise enjoy Abilene access, are now presented with that opportunity. We anticipate this very encouraging development will foster more pervasive access to the NGI and should generate some very fruitful outcomes.

In addition to High Performance Connections program funding, The University of Tennessee was jointly awarded $6.5m in 1998 by the NSF and the Ministry for Science and Technology of the Russian Federation for the MIRNet project—to provide Next Generation Internet services to collaborating US-Russian scientists and educators. The goals of the MIRNet project include assisting meritorious scientific collaborations requiring advanced, high performance internet services; connecting the Russian Next Generation Internet network to the US v BNS, and other next generation networks in the US and elsewhere; and, more broadly, encouraging and supporting productive cooperation between the US and Russian scientific communities.

The University of Tennessee, therefore, by virtue of its Carnegie I status, and its demonstrated need for high performance network connectivity, has been able to successfully compete for federal agency support, and has thus been enabled to fully participate in the NGI efforts being pursued under the aegis of Internet2, a consortium of over 170 U.S. research institutions, government, and over 50 industry partners.

With the enabling network infrastructure in place, The University of Tennessee has been positioned to pursue and secure additional funding, including awards from The Southeastern Universities Research Association for development and promotion of next generation video-over-IP technologies; from The NSF Knowledge & Distributed Intelligence (KDI) program for development of interactive, online supercomputing training modules; and from The NSF for a Scalable Intracampus Research Grid (SInRG) project for the deployment of a research grid on The University of Tennessee campus at Knoxville, mirroring the technologies and the interdisciplinary research collaborations that are characteristic of the emerging national technology grid.

Like many of the 100 research institutions awarded grants in the NSF High Performance Connections program, The University of Tennessee is faced with challenges to optimal use of its advanced networking capabilities. The challenges include last mile or local loop problems, i.e., the quality of the connection to the end user's desktop, and the need for campus networking upgrades, the characteristically high cost of high performance applications and the lack of funding for application development, the high demands on faculty time and lack of incentive to develop applications, the need for advanced middleware and resolution of network performance issues. Next generation internetworking in general, is still essentially a testbed environment, with network engineering issues, such as Quality-of-Service, yet to be resolved. Many of the technologies that can realize the benefits of broadband networks are emerging, and thus can suffer from poor interoperability, lack of standardization, and high cost.

The dearth of traffic and applications taking advantage of the advanced research network infrastructure is a cause for concern nationally, which, not surprisingly, has resulted in a reevaluation of the merits of funding infrastructure. Universities, such as The University of Tennessee at Chattanooga, which have not already received infrastructure funding, therefore, will likely find making a case to do so difficult. The NSF Division of Advanced Networking Infrastructure and Research has now recognized the need to support end-to-end application development through funding of advanced network services, and has concluded that direction and support in this area is vital for full utilization of our NGI resources to be realized. This conclusion has been fully endorsed in the Internet2 community. Certainly, although there is disappointmentwith the current state of application development, the essential infrastructure is now in place, thanks to federal agency support. It is critical that disappointment does not lead to this support being abandoned and a loss of momentum; continuing support will serve to enable us to exploit achievements to date and realize the full potential of the NGI.

While The University of Tennessee, like many of its peers, has faced challenges to application development, it has still been in a position to reap other benefits of membership in the NGI/Internet2 community. Some of the benefits of NGI participation are obvious—access to collaborative tools, remote virtual environments, remote instrumentation, distributed computing resources, and digital libraries, for example. However, as Research-1 institutions coalesce around the NGI/Internet2 focus, additional and equally significant benefits for their Information Technology organizations and constituencies have emerged-sharing of resources and expertise, development of a skilled IT workforce, emergence of multi-institutional partnerships and collaborations, and the leveraging of these partnerships towards more effective relationships with industry and the vendor community, and the opportunity to contribute to the design and implementation of the NGI.

The University of Tennessee has made good use of these membership advantages, and has demonstrated leadership in NGI/Internet2 in initiating and fostering multi-institutional collaborations, such as The Video Development Initiative, a multi-institutional effort to promote the deployment of digital video in higher education, and the Internet2 Distributed Storage Infrastructure (I2-DSI), a replicated hosting service for Internet content and applications. The University of Tennessee Health Science Center in Memphis is an active member of the "Early Harvest" Internet2 initiative which seeks to provide privacy, authentication and authorization tools to support medical applications. The Health Science Center and The University of Tennessee College of Veterinary Medicine are also participating in a new Health Sciences initiative sponsored by Internet2.

The University of Tennessee is currently endeavoring to leverage its own resources, and the collective resources it now has access to, towards application development. Brief descriptions of some of the applications underway at The University of Tennessee illustrate how NGI-enabled applications can enrich instruction and research.

Virtual Rounds is an application at The University of Tennessee College of Veterinary Medicine that entails the sharing of live animal clinical caseloads with the colleges of veterinary medicine in the southeast. Geographical obstacles have previously restricted veterinary teaching hospitals from sharing caseloads, but by taking turns at presenting live cases via high-quality teleconferences, the participating colleges can not only increase the number and variety of live animal cases their students are exposed to, but can also benefit from interaction with their peers. Sharing of clinical cases is the first step in the exploitation of emerging technologies and NGI capabilities for the sharing of resources and for collaboration in veterinary medical education.

Since 1995, the Radiology Department at The University of Tennessee Health Science Center in Memphis has utilized remote directed abdominal ultrasound, with a radiologist at a central site monitoring and directing ultrasound studies being actually performed by trained technologists at various sites throughout Memphis and West Tennessee. While one of these studies can be relatively easily accommodated on commodity telecommunications links, abdominal ultrasound is only one of many radiology studies which itself is a subset of other medical procedures. To mature from a niche application to comprehensive remote delivery of patient procedures will require significant additional aggregate bandwidth. In addition, The University of Tennessee Health Science Center operates training programs and has numerous clinical interactions at many sites, including Jackson, Dyersburg, Nashville, Knoxville and Chattanooga, while The School of Nursing in Memphis offers graduate degrees entirely over the Internet. However, with the congestion on today's commodity Internet, there are limitations to the scale and degree of interactivity achieved.

The health sciences arena is one that is likely to be greatly impacted by the NGI, but application developments are still in their infancy and much of the promise remains to be tapped. The National Institute of Health has been a strong advocate of the NGI but support for grass-root efforts and an ubiquitous high speed networking infrastructure for use in telemedicine, medical research and distance education applications is critical. With the enabling infrastructure in place, for example, The University of Tennessee at Chattanooga would be able to access the large gene databases located at the Department of Energy and other sites to support its participation in the human and mouse genome projects, and enhance its offerings in biological science education.

The University of Tennessee is partnering with regional and national networking organizations (The National Laboratory for Applied Network Research (NLANR), the National Center for Atmospheric Research (NCAR) and the Pittsburgh Supercomputing Center) to work towards a solution to the poor performance of large file transfer. The short-term goal is to meet theimmediate demand at The University of Tennessee for large data transfer, demand from faculty/researchers in High Energy Physics, and Computer Sciences, for example. Over the long-term, the envisioned goal of this project, called Web100, is to arrive at improved performance in commercial host software in general in order to fully avail of bandwidth.

The University of Tennessee has recently accelerated its application development, and is also planning additional applications, including the development of virtual design studios for use in architectural instruction and research, the creation of high-quality on-demand live and archived digital video assets for use in all disciplines, digital library development, and the fostering of collaborative opportunities through the development of a high-quality teleconferencing-over-IP service.

Finally, with the recent award to The University of Tennessee and Battelle partnership of the management contract for The Oak Ridge National Laboratory, The University of Tennessee, Oak Ridge Associated Universities (Duke University, Florida State University, Georgia Institute of Technology, North Carolina State University, University of Virginia and Virginia Tech), and The Department of Energy will now be able to pool and leverage NGI resources and expertise towards supporting and fostering excellence in areas such as neutron science, distributed computing, biotechnology and advanced materials, and network research.

"Advanced Networking for All of Higher Education: Recommendations and Report from the Institutional Opportunities for Advanced Networking" Net@EDU Conference, January 1999, Austin, Texas: p. 7.

CONCLUSIONS

In conclusion, I hope my testimony demonstrates the eagerness of The University of Tennessee at Chattanooga to participate in the NGI/Internet2. I hope that I have also shown that funding for enabling infrastructure is just the beginning, and much more can be achieved if federal agency support continues. One recommendation would be to change the Internet2 fee structure to allow levels of membership based on an institution's expected use of the network. Current network use does not even come close to exceeding bandwidth limits, and the benefits gained from expanded access to campuses like The University of Tennessee at Chattanooga are far greater than the risk of system overload.

The higher educational community is just starting to witness the first fruits of the NGI, but already there is ample evidence of the contribution the NGI is likely to make to successfully fulfill our research, instruction and public service missions in the 21st Century.

In closing I would like to leave you with this. The steel rails used to deliver goods and information in the past have been replaced by miles of electronic fiber. Since the fiber network largely follows the rail lines, the University of Tennessee at Chattanooga is well situated geographically to access the fiber networks necessary for NGI and Internet2 use. The dream of a Tennessee Technological Corridor running from Knoxville to Oak Ridge to Chattanooga will not be a reality until The University of Tennessee at Chattanooga is afforded participation in the NGI and Internet2. Oak Ridge, Tennessee, well known as a major computational center, is only 90 miles from Chattanooga; however, it may as well be across the country because of The University of Tennessee at Chattanooga's inability to access it through a high speed network. Please help us bridge that 90 miles, and we guarantee the investment will be multiplied in return.

Senator FRIST. Thank you, Dr. Stacy.
Mr. Tolbert.

STATEMENT OF STEPHEN TOLBERT, PRESIDENT AND CHIEF EXECUTIVE OFFICER, GLOBAL SYSTEMS & STRATEGIES, INC.

Mr. TOLBERT. Thank you, Senator Frist. I thank you for the opportunity for inviting me to speak about this compelling issue.

I am Steve Tolbert. I am the President of Global Systems & Strategies. We are a small, fast-growing network architecture design firm. My company provides high-end network engineering consulting services to a variety of private sector clients as well as government agencies, including the Health Care Financing Administrator, Department of Defense, and the Food and Drug Administration.

I am also a member of the Northern Virginia Technology Council Board of Directors and Executive Committee. And as such, I am the founder and Chair of NVTC's Telemedicine Working Group, which is a new regional initiative in telemedicine.

In speaking today, I represent the perspective of my firm as well as other private sector interests in high technology, as both consumers and also designers of Internet services, and also the perspective of the NVTC Telemedicine Working Group.

Our society's dependence on information technology and the Internet services that glue us together is growing at a staggering rate. Every day more businesses, more Federal, state and local government agencies and more individuals jump to new Internet-based services and technologies as a way of getting just about anything done.

To appreciate our increasing dependency on technology, we need only look back 60 days at the Y2K scare. America's public and private sector businesses stopped forward progress on many fronts and spent billions of dollars vaccinating themselves against the Y2K bug. Families across the country even built bunkers, with months of supplies, certain that society would grind to a halt with crippled technology.

We are squarely in the midst of the information age, and our way of life depends on how we embrace this new order. The Internet is at the center of this dramatic trend. It has become the connecting fabric of today's modern business and even today's modern family. We hand out E-mail addresses as readily as we hand out phone numbers today.

From Fortune 100 businesses to local, family owned produce farms, almost every business uses information technology and the Internet in some capacity. Today, the Internet is at an interesting crossroads. Based partly on 20-year-old technology, the Internet's capacity and capabilities are being exhausted by our amazing ability to think up new ways to use it. It is literally becoming a victim of its own success.

Today's Internet will not support tomorrow's demands. We must begin implementing NGI now to protect our current rate of progress and also our global leadership. For example, we are fast depleting available unique addresses on the current Internet. While work-arounds are available that may extend current addressing schemes, they compromise other key features and only solve the problem for particular uses of the Internet.

On the other hand, the address space offered by NGI could provide up to 32 unique addresses for every square inch of dry land on the planet. Not terribly useful—as a mathematician with too much time on his hands—but it is a clear indication that we will not be facing this problem again for generations if we adopt NGI.

Other problems relate to the current technology's inability to adequately support new uses, such as transmission of high-speed real-time multimedia images, like complex medical images or full-screen, full-motion video conferencing. A single MRI image can include up to 20 gigabytes, 20 billion bytes of information, which, over a standard dial-up Internet connection, would take roughly 38 days to transmit. I would submit that in some cases the transmission would outlast the patient.

If you are fortunate enough to have access to a, quote, unquote, high-speed T–1 connection, it would take more than 30 hours. A typical connection to NGI would move this image in 30 seconds, and allow real-time diagnosis.

Finally, our national telecommunications infrastructure does not provide adequate access to today's Internet. While most regions have telephone access, and therefore low-speed access to the Internet, many rural areas do not have higher-speed services critical for applications such as, again, telemedicine.

Consider the transmission of medical images—even less complex x-rays. Support for full-motion, full-screen video conferencing between remote patients and physicians or specialists requires three to six times the speed of a standard telephone line. Rural access to NGI could support such services as lifelike video conferencing and real-time transmission of medical images, including full-motion images, such as ultrasound.

There are more esoteric applications, such as telerobotic surgery, that are made possible by the bandwidth promises of NGI. These advantages, or advances, would not only change the cost of rural health care and, in fact, national health care, they would save lives.

The Next Generation Internet and its supporting technologies can solve many of the current obstacles and truly enable the next generation of information technology. For example, NGI supports high-speed multimedia transmission, including voice, enhanced security, vastly increased addressing, and more robust fault resistance. But while many of the specific technologies needed have been developed by various public and private consortia and research organizations, there is still substantial work ahead to make NGI viable and a national solution.

Additional research in high-speed, high-availability network technologies is needed to produce the next wave of higher-speed yet inexpensive network equipment and software. Specifically, research is needed to support affordable high-speed rural access with technologies such as wireless and satellite communications. There is also much work to be done planning the transition to NGI. The process of migrating the Nation's pervasive Internet technology to a new generation of technologies is non-trivial and, by some estimates, may cost up to $100 billion.

I would argue, however, that the alternative of an exhausted Internet would cost more, through lost revenues, lost competitive edge, and the inability to deliver needed services. If we agree, then, that the reasons to move NGI are clear and compelling, the remaining question becomes: Why should the government dedicate substantial funds to the issue? Why won't natural market forces compel the high-technology industry to develop and deploy NGI on its own?

I would argue that substantial progress on specific fronts by private industry is probably inevitable. However, I would also argue that the development of a coherent solution in the timeframes needed before the current Internet becomes a barrier is unlikely without additional motivation and focus. For example, without directed research, few companies would make near-term investments in high-speed rural access. The economics simply do not support it.

In this case, there is a divergence between the national interests on the one hand and the competitive interests and pressures of the private sector on the other. As I stated earlier, to ignore the rural access issue could cost lives. Motivated by Federal support, industry could develop and deploy technologies that, in providing lower-cost rural access, could improve availability of quality health care and help to narrow the digital divide.

Federal investment and coordination would also provide two other fundamental benefits. It would certainly accelerate progress toward a faster, more robust national telecommunications infrastructure. Furthermore, it would serve to homogenize the diverse efforts of those involved, leading to national technical standards and avoiding the frequent delays introduced by competing proprietary technologies.

Other dividends produced by the investment would include the following: First, achieving a faster, more robust national telecommunications infrastructure would support additional economic growth, not just in the high technology industry, but across every industry that could benefit from universal access to fast, reliable communications. There is clear precedence in the dividends produced by investments in the technology sector—a sector that accounted, as Dr. Lane pointed out, for roughly one-third of the economy's growth between 1995 and 1998.

Second, the country has enjoyed global competitive leadership that in fact began with similar investments in infrastructure that fueled the industrial revolution 100 years ago. Accelerating the deployment of a more capable infrastructure would help to sustain this leadership, both business-to-business relationships and collaboration among research and educational institutions would be enhanced.

Often overlooked in discussions about advanced technology investments, the social impact of an improved national telecommunications infrastructure would be profound. Again, regarding telemedicine, the impacts on the delivery and access to timely, high-quality health care services alone could improve the quality of life.

Finally, the government itself is a substantial consumer of telecommunications services and would benefit directly from accelerated deployment of a faster, more secure telecommunications infrastructure, though, admittedly, this would be initially tempered by the government's own transition costs.

In conclusion, I strongly support the changes to the Next Generation Act that this subcommittee is considering, and I again appreciate the opportunity to speak to you today about this.

[The prepared statement of Mr. Tolbert follows:]

PREPARED STATEMENT OF STEPHEN TOLBERT, PRESIDENT AND CHIEF EXECUTIVE OFFICER, GLOBAL SYSTEMS AND STRATEGIES, INC.

Chairman Frist:

My name is Steve Tolbert and I am the president of Global Systems & Strategies, Inc., (GSS) a small, fast-growing network architecture design firm in the mid-Atlantic region. My company provides high-end network engineering consulting services to a variety of private sector clients as well as Government agencies such as HCFA, DOD, and FDA. I am also a member of the Northern Virginia Technology Council (NVTC) board of directors and executive committee, and as such, am the founder and chair of NVTC's Telemedicine Working Group. In speaking here today, I represent the perspective of my firm, as both a consumer and designer of Internet services, as well as that of the NVTC Telemedicine Working Group.

Our society's dependence on information technology and the Internet services that glue us all together is growing at a staggering rate. Every day, more businesses, more federal, state, and local government agencies, and more individuals jump to new internet-based services and technologies as a way of getting just about anything done. To appreciate our increasing dependency on technology, we need only to look back 60 days at the Y2K scare. America's public and private sector businesses stopped forward progress on many fronts and spent billions of dollars vaccinating themselves against the Y2K bug. Families across the country even built bunkers stocked with months of supplies, certain that society would grind to a halt with crippled technology. We are squarely in the midst of the information age and our way of life depends on how we embrace this new order.

The Internet is at the center of this dramatic trend. It has become the connecting fabric of today's modern business and even today's modern family. We hand out e-mail addresses as readily as we hand out phone numbers. From Fortune 100 businesses to local, family-owned produce farms, almost every business uses information technology and the internet in some capacity.

Today, however, the internet is at an interesting cross-roads. Based partly on twenty-year old technology, the Internet's capacity and capabilities are being exhausted by our amazing ability to think up new ways to use it. It is becoming a victim of its own success. Today's Internet will not support tomorrow's demands—we must begin implementing the Next Generation Internet (NGI) now to protect our current rate of progress and our global leadership.

For example, we are fast depleting available, unique addresses on the current Internet. While work-arounds are available that may extend current addressing schemes, they compromise other key features and only solve the problem for particular uses of the Internet. The address space offered by NGI could provide up to 32 unique addresses for every square inch of dry land on the planet—not terribly useful, but a clear indication that we would not be facing this problem again for generations.

Other problems relate to the current technology's inability to adequately support new uses such as transmission of high-speed, real-time multi-media images like complex medical images or full-screen, full-motion video conferencing. A single MRI image can include up to 20 gigabytes of information, which, over a standard dial-up Internet connection, would take roughly 38 days to transmit. If you're fortunate enough to have access to a "high-speed" T-1 connection, it would still take more than 30 hours. A typical connection to NGI would move this image in 30 seconds.

Finally, our national telecommunications infrastructure does not provide adequate access to today's Internet. While most regions have telephone access and therefore, low-speed access to the internet, many rural areas do not have higher speed services critical for applications such as telemedicine. Again, consider transmission of medical images, even less complex x-rays. Support for full-screen, full-motion video conferencing between remote patients and physicians or specialists requires 3—6 times the speed of a standard telephone line. Rural access to NGI could support such services as life-like video conferencing and real-time transmission of medical images (including full-motion images such as ultrasound.) These advances would not only change the cost of rural health care—they would save lives.

The Next Generation Internet and its supporting technologies can solve many current obstacles and truly enable the next generation of information technology. For example, NGI supports high-speed multi-media transmission, including voice over IP, enhanced security, vastly increased addressing, and more robust fault resistance. But, while many of the specific technologies needed have been developed by various public and private consortia and research organizations, there is still substantial work ahead to make NGI a viable, national solution.

Additional research in high-speed, high-availability network technologies is needed to produce the next wave of higher speed, yet inexpensive network equipment and software. Specifically, research is needed to support affordable, higher-speed rural access with technologies such as wireless and satellite communications. There is also much work to be done planning the transition to NGI. The process of migrating the nation's pervasive Internet technology to a new generation of technologies is non-trivial, and by some estimates, may cost up to $100 billion. I would argue, however, that the alternative of an exhausted internet would cost more through lost revenue, lost competitive edge, and the inability to deliver needed services.

If we agree that the reasons to move to NGI are clear and compelling, then the remaining question becomes, "why should the federal government dedicate substantial funds to the issue?" Why won't natural market forces compel the high-technology industry to develop and deploy NGI?

I would argue that substantial progress on specific fronts by private industry is probably inevitable. However, I would also argue that the development of a coherent, more capable national telecommunications infrastructure that, at the same time treats both rural, individual access and urban, Fortune 100 access in the timeframes needed before the current Internet becomes a barrier, is unlikely without additional motivation and focus.

For example, without directed research, few companies would make near-term investments in high-speed rural access—the economics simply don't support it. In this case, there is a divergence between the national interest on the one hand and the competitive interests and pressures of the private sector on the other. As I stated earlier, to ignore the rural access issue could cost lives. Motivated by federal support, industry could develop and deploy technologies that, in providing lower cost rural access, could improve availability of quality health care and help to narrow the digital divide.

Federal investment and coordination would also provide two other fundamental benefits. It would certainly accelerate progress towards a faster, more robust national telecommunications infrastructure. Furthermore, it would serve to homogenize the diverse efforts of those involved, leading to national technical standards and avoiding the delays introduced by competing, proprietary technologies.

Other dividends produced by this investment would include the following:

- Achieving a faster and more robust national telecommunications infrastructure would support additional economic growth, not just in the high technology industry, but across every industry that could benefit from universal access to fast, reliable communications. There is clear precedence in the dividends produced by investments in the technology sector, a sector that accounted for roughly ⅓ of the economy's growth between 1995 and 1998.
- This country has enjoyed global competitive leadership that in fact began with similar investments in infrastructure that fueled the industrial revolution 100 years ago. Accelerating the deployment of a more capable telecommunications infrastructure would help to sustain this leadership. Business to business relationships and collaboration among research and educational institutions would be enhanced.
- Often overlooked in discussions about advanced technology investments, the social impact of an improved national telecommunications infrastructure would be profound. The impact on the delivery and access to timely, high-quality health care services alone could improve quality of life across the country.
- Finally, the government itself is a substantial consumer of telecommunications services and would benefit directly from accelerated deployment of a faster, more secure telecommunications infrastructure, though, admittedly, this would be initially tempered by the government's own transition costs.

In conclusion, I strongly support the changes to the Next Generation Internet Act under consideration by this subcommittee.

Thank you for allowing me the opportunity to speak to you today about this compelling and timely issue.

Senator FRIST. Thank you, Mr. Tolbert.

Let me ask each of you a couple of questions. Dr. Meredith, you commented on the desire of many non-ESPCoR states to participate in the program because it does respond to a basic need, basic infrastructure support, that is necessary to enhance a national research base. Do you believe this need for infrastructure support may become a national problem as we go forward into the future?

Dr. MEREDITH. I do not think there is any question about it, Senator. We cannot do our work. We have so much capability on so many campuses that are not located in all the places that my good friend, Chancellor Stacy, was talking about. We have such incredible pockets of talent that need to have an outlet. And if that infrastructure is not present, if it is not there to allow that outlet to occur, the Nation loses. Our states lose.

As you know, ESPCoR particularly is directed toward research that benefits that state in particular and the Nation, as well. But it must directly impact that state. All that is lost if the infrastructure is not available to allow those people the access.

Senator FRIST. Chancellor Stacy, could you comment on how membership in Internet II factors into who receives grants from the NSF and other Federal agencies?

Dr. STACY. The first part of the access is that connectivity. And that becomes really the first part. And for small institutions such as ours, for instance, you start by needing to pay a membership fee in UCAID. And then it becomes a matter of your need to purchase additional somethings, maybe like Abilene, the connectivity, and on and on. And then it becomes the phone line. It costs about $300,000 for the first step, just to begin.

Once that $300,000 is expended and you achieve the memberships, then you are able to play in the arena, to seek the NSF grants and other things. But it is that first level of connectivity that is the barrier to many. Sometimes it is the last mile of the phone line that has to bring that potential to you.

So, just in every case, it is a priority choice to decide where does that $300,000 investment go, and it is so critical and we ought to be making it. And yet, across the country, if we only have that done in 150 places out of 4,000 schools, we are missing potential and we are leaving faculty, very bright people, stranded by having simply not the access to it.

Senator FRIST. When Dr. Colwell said the NSF is reaching—when I said what you were going to say—and she said they were reaching out in other areas, could you put that in perspective for us?

Dr. STACY. Well, yes. As a member of the Internet II, the University of Tennessee Knoxville campus was the recipient, in 1997, of that NSF high-performance connection grant of $350,000. But you have got to get there first. And one of the items that I would I guess plead as you bring the revisions to the bill is that that basic first step of access be provided in some way. Maybe it is a prorated part of use. Maybe it is a part of the flagship campus. Maybe it is related to a national lab nearby. We sit 80 or 90 miles from Oak

Ridge, 100 miles from Knoxville, and it is as much as if it were 1,000 miles.

Senator FRIST. The other programs that she mentioned, do you take advantage of any of those that Dr. Colwell mentioned?

Dr. STACY. And it is that first level of access. If you do not get the connectivity, you are shut out of any of them. So it is such a first step for us that it is a big part.

Senator FRIST. Mr. Tolbert, first, thanks for your testimony. Your examples in there and your medical examples are very useful to me. Because a lot of people, both I am sure in your business, though you are consulting with people who already understand what they need or you help them understand what they need, but when you talk about the Next Generation Internet, it is very helpful to have very specific examples, whether it is medical images, comparing it to what comes through the telephone line or your other examples in terms of imaging and T–1 connections and what they do from MRI's.

I am fascinated and would ask you to elaborate on your comment right at the end of your presentation about how Federal investment can homogenize and help in some way sort out a mishmash, diverse environment, and give some discipline in terms of standards that can then be promulgated out to the private sector. Could you comment on that and the role of government vis-a-vis an environment of competing technologies? Each of them, I am sure, want to develop their own standards.

Mr. TOLBERT. I think it is a very important aspect of what you are trying to do. And I think that, as you know, the industry sort of creates new ideas and new value in the Internet economy. And it is not so much in evolutionary steps, it is explosive steps. And it is very difficult to sort of get ahead of that activity and provide some guidance. And a lot of the explosive steps that are successful and that sort of take tend to have sort of direct economic value. And that is what drives them.

And I think that what that often leads to, however, is, one, competing standards, or technologies that address sort of 80 percent of the problem or, in some cases, 20 percent of the problem, with 80 percent of the economic gain. And so I guess my feeling about the role of Federal investment and the ability to select how grants are made and what activities are supported is the ability to sort of help steer the explosion of these new technologies so that we do not develop multiple competing technologies, we do not ignore the last mile and rural regions, for example, where, again, the economic model simply does not support what most companies would invest on their own.

So, again, it is not only helping fill in the gaps where the private sector would not address technology, but it is also making sure that most of the explosions are in a consistent direction and with some vision that is useful in the broader sense. I think that a lot of companies are driven by relatively short-term vision and returns as opposed to something that we need to do today that will affect us substantially in 5 or 10 years. And I think that by directing investments you can effect that direction.

Senator FRIST. Thank you.

Dr. Stacy, what about recruitment? Since we are on this huge or rapidly climbing curve in terms of Internet technology that we hope to make even more rapid in terms of its ascent. When you talk to faculty and students—and again, I was reminded when the young students were in here earlier today—when you are recruiting faculty and students, how important is the access to high-speed networks like NGI, Abilene, in your ability to recruit?

Dr. STACY. Your instincts are exactly right on. When that digital divide separates that faculty member who has been at the research 1, the doctoral program, has utilized the greatest sophistication of combinatorics, when that computational sophistication is not available at the next place, how does that person continue his or her research?

So it sets up, again, the divide, of that very best faculty member whom you want has had that experience. And to move to another institution lacking it is just very tough on that faculty member. It has implications to the curriculum. It has implications then to the faculty. It does set up that have and have-not.

Senator FRIST. Dr. Meredith, let me sort of keep with that theme of faculty, faculty recruitment. And considering that your state must struggle to meet the connection costs to permit these cutting-edge advanced technologies, do you find that the system in Alabama has adequate faculty to aggressively compete for grants, the grants that are out there—faculty and let us take it down to graduate students, as well?

Dr. MEREDITH. We are in a constant struggle to stay in that battle. We require at our three research universities that they generate a significant portion of their operating expenses in income. And we have been very successful at that, I would say, very competitive, at all three institutions.

But in order to have those kinds of faculty members who can generate those kinds of dollars that also keep the rest of the institution going, we have got to have the technology support for them. And bringing in the Gigapop into our three institutions has been an enormous boon to us in order to keep the faculty members we have.

They now have access to—I would love to take you for an hour through the kinds of things that are going on now in our institutions—optical electronics, with advanced microchips, just on and on. The new advances of medicine, with biomaterials engineering, with implants, and so forth. They are able to be in concert with their colleagues, in collaboration with their colleagues, all over the country. And they can do that from our institutions now. They do not have to move now and go somewhere else.

I have a great E-mail here from one of our leading astronomy professors, who is in collaboration with some folks in Arizona. What he can do now downloading at our institution from a telescope in Arizona is unbelievable. He is just ecstatic in his E-mail, that he is now competitive. He can collaborate with people anywhere in the country and around the world and maintain his research and stay in Alabama and get that done. It is just essential.

Senator FRIST. Dr. Stacy, the University of Tennessee's participation in the MIR Net project would provide Next Generation Internet services to Russian scientists and educators. Could you tell me a little more about that?

Dr. STACY. That is a collaboration, as both countries, scientists in both places, are looking at that next generation. I think it meets the U.S.'s ambition of having collaborative scientific endeavors. We live in this global village, and we are finding a great deal of bright colleagues there with whom to work. It is a part of an effort that says that intellect is not bound up at some national border.

Senator FRIST. Are there other international collaborative projects going on that you are participating in?

Dr. STACY. I do not know of others similar to MIR net.

Senator FRIST. Dr. Meredith.

Dr. MEREDITH. We have a number. And one of the things we have found so interesting lately is the collaboration now that is going on across borders, and as we look at research articles coming out, no longer are there one or two people on so many of those articles. Now there are six or seven or eight or 10 people, and they are located all over the world. And they collaborate now because they have the ability to move their research back and forth and come to some wonderful discoveries together.

Senator FRIST. In my own field of medicine, before coming to the U.S. Senate, it was very early on, but—now it seems like ancient history, based on all the discussions and the speed with which things have moved—but it was fascinating in terms of scientific cooperation across borders, which, in 1993 it was almost unheard of. In 1994, when we first began to understand the Internet, it changed and even advanced pediatric heart transplantation and basic immunology. And of course now it is the rule.

Mr. Tolbert, do you feel that the pace of NGI research—we talked a little bit about funding and this doubling curve, but in terms of the research itself, the substance of the research, the pace, the advance, is it able to meet what you perceive are the private sector's needs or demands in a timely fashion?

Mr. TOLBERT. If I were to consider concepts to commercialize the application of technology, I would say that it is not able to keep up with demand. I think that it takes quite a bit of activity to get a concept to the point where it is sliding down the price slope. And that is when it becomes commercially viable, or viable for consumption. And that typically takes a tremendous amount of time. I think that it is happening today with NGI technologies.

At the same time, I would say that in some specific areas there have been great strides. And certainly what is in place now and the connections that these two gentlemen benefit from are a great example of the fact that some of the technologies are there now and can be deployed and made useful.

But, again, I think my overall comment would be that there is not enough going on and not enough urgency to make it commercially viable to keep up with demand. I think that, in general, demand is always just slightly ahead of what is available to support it.

Senator FRIST. You talked in your testimony about the cost and you threw a figure out. And since I may use that figure I want you to help me with it. The cost of migrating the Nation's pervasive Internet technology to a new generation of technologies is not small, not trivial, as you said. And you had the figure of $100 billion in there. Before I go and use it, I want you to tell me where that estimate roughly comes from.

Mr. TOLBERT. If I am not mistaken, and I will verify this after I leave, that it is from a Department of Commerce study.

Senator FRIST. And the types of activities that this deployment would involve are what?

Mr. TOLBERT. If you think of it in terms of infrastructure, certainly there is equipment and software that simply needs to be deployed. There is also physical connections that need to be made between huge high-speed hubs for the new infrastructure. But there is also organizational planning on the part of individual consumers.

There is a very specific transition of technology. There is sort of an evolution from one technology to the other and, at some point, probably coexistence of multiple protocols like IP version 4 and IP version 6. And all of that takes a great deal of planning. It is something that is probably done incremental. And out of that came this estimate.

There is a very important issue, I think. When you think back, again, 60 days, on the huge investment that was made in Y2K inoculation, the investment was made, billions of dollars, basically to be able to stay in business on January 2nd the way you were 2 days before. And there was not, in most cases, a substantial return on that investment, other than the fact that it certainly stirred up a lot of economic activity.

In this case, this is $100 billion to purchase substantial new capability. So it is not just doing it because we are tapped out and we have run out of bandwidth. It is actually making an investment, but getting a quantifiable return for large organizations. So it is important to note that it is a staggering number but, at the same time, there is direct, tangible, measurable benefit coming out of that investment.

And, again, if I am not correct on the source, I will contact your office.

Senator FRIST. Fine, that would be helpful.

I will close with this, and I appreciate everybody's patience. It is fascinating for me, and I do want to make sure we are moving in the right direction and that we learn from each round as we go through. So the oversight function part of what we are talking about today is very important to help give us direction.

One last question, Mr. Tolbert, and it goes back to the international component. Our leadership in the United states, the industrial revolution, the parallel that you made, right now where we are versus other nations, is commerce slowed down or impeded? Obviously when you get to imaging, medical imaging, broadband transmission of data, more video, it is going to be slowed down. International transmission of data now, is it slowed down because our infrastructure is more advanced than other countries?

Mr. TOLBERT. I think that in certainly some industries it has. Ironically, in some countries that have made very specific investments in high-speed infrastructure, telemedicine is more advanced, or, not necessarily more advanced, but more pervasive and put to use more commonly.

At the same time, there is sort of a natural evolution to Internet maturity, where it starts with kind of Internet publishing and graduates to commerce and competitive advantage. And I think that in that sense we hold the lead by a substantial margin. And this is according to a recent study by IDC. That will be impeded, though.

If you agree that three times the number of current users will be online in three years and, at the same time, they are going to be online for longer periods of time, using applications that are much thirstier and can use substantially more bandwidth, you will end up hitting some barriers in that continued leadership. And I think that that is where I see the investment needed today to start moving in that direction rather than to waiting until we start to see those choke points.

Senator FRIST. Thank you.

To all three of our witnesses and the witnesses of the first panel, I want to thank you. Your expertise and your analysis are tremendously helpful as we go through and try to better understand the true nature of the current Internet's limitations. Your recommendations are tremendously helpful as we improve legislation that has previously been before this committee and as we look at other legislation.

I look forward to continuing the dialog that we have begun and continued today. And I look forward, again, in hearing, either next year or 12 months from now, what we can learn, should have learned, from our discussions today as we go forward. Again, thank you very much.

With that, we stand adjourned.

[Whereupon, at 4:30 p.m., the hearing was adjourned.]

APPENDIX

PREPARED STATEMENT OF HON. JOHN B. BREAUX,
U.S. SENATOR FROM LOUISIANA

Chairman Frist, I want to thank you for kicking off the Science Subcommittee's agenda by examining the future of the Internet, specifically the Next Generation Internet (NGI) and Large Scale Networking programs. This is an appropriate topic—advances in technology are strongly linked to economic growth. Our dominant high technology industries are currently responsible for one-third of our economic output and half of our economic growth. Federal Reserve Chairman Alan Greenspan stated last year that an unexpected leap in technology is primarily responsible for the nation's "phenomenal" economic performance.

The folks who make and program the computers aren't the only ones sharing in this economic growth. The Internet its world wide web are giving us new ways to communicate—and do business—electronically.

Our nation has made great strides using the current Internet, and we can all just imagine what advances we could make with a higher-bandwidth, more reliable Next Generation Internet. We could have the network capacity to monitor and integrate information from thousands of sensors to improve our responses to floods, hurricane, or other natural disasters. This research could make robotics a part of our daily lives and staying in touch everywhere with wireless, high-speed connections regardless of where we live or work.

But as we look to the technological advances which could revolutionize information technology, we must also remember that not all Americans are sharing in the current high-tech prosperity. The current Internet is not available to a disproportionate number of low income and minority Americans and of Americans living in rural areas. As the NGI program continues, we should make sure that the structure of our future networking infrastructure does not build in more problems, like higher cost of access for rural users. I look forward to addressing these concerns today.

Dr. Lane, I am sure that you will rightly point out that the Next Generation Internet and Large Scale Networking are only a small part of the Federal investment in information technology research and development (R&D). While expanding the capacity and reliability of the Internet is an important piece, it is only one piece of a broader information technology R&D agenda. I look forward to working with you to address that broader agenda as well.

I would like to congratulate the Administration for the level of R&D investment spelled out in the FY 2001 budget. While I am sure that many of us would have prioritized spending by each agency differently, the overall increase of $2.5 billion or 6% over the FY 2000 level for civilian R&D is in line with this subcommittee's commitment to doubling civilian R&D over the next ten to twelve years.

Finally, welcome to all of our witnesses from government, industry and academia. You can all give us a different perspective on the current NGI program and what investments are needed to build an Internet of the future that is available to and affordable for every American.

PREPARED STATEMENT OF HON. ERNEST F. HOLLINGS,
U.S. SENATOR FROM SOUTH CAROLINA

Chairman Frist, thank you for holding this hearing today on the Next Generation Internet (NGI) program and the NGI 2000 Act, S. 2046, which Senators Rockefeller, Breaux, Roberts, and I joined you in introducing in February. This bill is a straightforward and basic authorization of funding for the Next Generation Internet (NGI) and is based on the Administration's NGI policy.

Everyone acknowledges that the current Internet is a huge commercial success and consequently is becoming a victim of its own success. With more and more subscribers, the Web is getting more and more crowded, and the response time is growing slower and slower.

The NGI program is focused on advancing the current speed and usability of the Internet and university research capabilities while assisting federal agencies in their missions using these resources. The NGI can provide the critical research into the necessary technology to get the U.S. to the next phase and to maintain U.S. dominance in this field.

When we created NGI in 1998, we laid out a bold set of expectations for the first three years of the program. Plainly and simply, we set an action plan to overhaul the Internet's infrastructure. Three years later, this hearing should help us learn what the program has achieved, where it should go, and what our future investments in networking infrastructure should be.

With all of the hoopla about the so-called "digital economy" and ads for dot-com companies on every billboard, it's easy to forget the folks who the Internet has passed by. Members of this Committee have tried to bring the current Internet to minority, low-income, and rural communities. We must ensure that as we look to the Next Generation Internet, that high-speed technology is available to these communities. Senator Frist, your bill makes a good start by setting aside some research funding for solving rural problems and to be spent at small or minority-serving colleges. The bill also would ask the National Academy of Sciences to address the contribution that the network infrastructure makes to the digital divide—the gap between those with access to information technology and those without access.

Again, thank you for holding this hearing. We have a wonderful lineup of witnesses, and I look forward to examining further these issues through their fine testimony.

PREPARED STATEMENT OF DOUGLAS VAN HOUWELING, PRESIDENT AND CEO, UNIVERSITY CORPORATION FOR ADVANCED INTERNET DEVELOPMENT

Advances in information technology, critical to the continued success of science and education in our Nation, depend upon active Federal support and investment. The introduction of the Next Generation Internet (NGI) 2000 Act, S. 2046 is a welcome step to continue and expand Federal networking research authorized by the NGI Act of 1998. I commend Mr. Frist and Mr. Rockefeller and members of the Senate for their leadership.

Internet2™ now engages more than 174 universities, over 10 corporations and 30 other research organizations in the effort to advance the state of Internet applications and technology. Internet2 collaborates closely with industry and government in advancing research in information technology, providing a living laboratory for building and deploying advanced networks, services and applications. In particular, Internet2 is working to enable applications such as telemedicine, digital libraries and virtual laboratories that are not possible with the technology underlying today's Internet. Internet2 is not a single network, but rather joins member network application and engineering development efforts together with many advanced campus, regional and national networks.

The university-led Internet2 and the federally-led Next Generation Internet (NGI) are complementary, but separate, initiatives successfully working together in many areas. For example, a number of Internet2 members have participated in the National Science Foundation's (NSF) merit-based High Performance Connections program.

The backbone networks supporting Internet2 universities work together with the NGI testbed networks to provide a seamless high-performance networking environment for researchers located on both university campuses and in government laboratories. The NSF's very high performance Backbone Network Service (vBNS) developed by the NSF and MCI Worldcom serves as one of the two (along with the Abilene network run by Internet2 members) national backbone networks used by Internet2 members. Internet2 engineers are engaged in regular coordination with NGI agencies through the Joint Engineering Team.

Universities are a principal source of both the demand for advanced networking technologies and the talent needed to implement them. Universities' research and education missions increasingly require collaboration among people and resources located at campuses throughout the country, in ways not possible using today's Internet. The NGI supported testbeds fill a critical role—they are very large-scale Internet environments in which cooperative research, testing and development can be carried out. The environment provided by the ESNet, NREN, DREN, vBNS and Abilene networks provides a crucial link between the laboratory and the information technology industry. Without this link, many promising basic research results would go untested and undeployed as the commercial marketplace focuses on short-term results and solutions.

Participation in Internet2 is based on a commitment by members to the goals of establishing high-performance connectivity among one another and developing and deployment of advanced network applications and technologies on their own campuses. Membership in Internet2 is open to any institution ready to provide the resources to realize these goals, and over 170 universities have joined since Internet2 began in October 1996. Collectively Internet2 universities have committed over $70 million per year in new investment on their own campuses to meet the goals of the Internet2 project. While the large-scale nationwide backbone networks are a crucial link between member institutions, the real challenge is getting high-performance networks not just to the edge of the campus but to each desktop on campus. This "end-to-end" focus on high-performance networking by Internet2 members requires substantial commitment of resources by each member—largely to be spent on their own campuses.

A primary goal of Internet2 is to ensure the broad dissemination of advanced networking capabilities. Understanding that participation in Internet2 is not something every institution will undertake, Internet2 member universities have developed a structure to enable non-members to collaborate with them on important advanced Internet research and education applications. For example, a number of Internet2 universities have ongoing collaborations with K-12 schools and will be able to collaborate with them on projects over their own regional high-performance networks as well as over the nationwide Abilene network. We expect this collaboration to lead to exciting new partnerships with other educational institutions, museums, libraries and small start-up companies among others.

We applaud the reauthorization of the NGI and note that this is but a part of a larger IT initiative that we believe also deserves Congressional support. The larger, balanced portfolio in information technology research and development brings to bear Federal support for Education and Training, IT Research Centers and Hardware Acquisition in addition to supporting Network research and development. These other programs we believe are necessary to maintaining the partnership that has created the US multibillion dollar industry.

This NGI authorization legislation is needed to renew the partnership between academe, industry and government. Internet2 will continue to work to develop and diffuse new technology needed by *all* network users, helping to ensure continued US leadership in computer and communications in the world economy.

RESPONSE TO WRITTEN QUESTIONS BY HON. BILL FRIST TO DONALD A.B. LINDBERG

Question. For your agency's participation in the NGI program, would you offer some perspective on how and how much health care costs may be decreased as a result of advanced networking research? Also, would you also address the impact of improved quality of service and effectiveness of service?

Answer. The cost of healthcare may or may not decrease as a result of advanced networking research. This would be dependent on the cost of the technology that advanced networking was replacing and on the future cost of what today is considered advanced networking. But the quality and timeliness of healthcare will improve through the appropriate use of advanced networking capability. For example, a person comes to a family doctor with a skin rash and the physician is unable to make a diagnosis. The patient is referred to a dermatologist. There is a delay until the patient can be seen by the dermatologist and treatment is started. And the patient has to take off from work to go to two appointments. If the family doctor can obtain a consultation from a dermatologist through advanced networking technology, treatment can be started immediately and the patient has to go to one appointment. This is clearly better and more timely healthcare, but the costs are dependent on how one does the cost accounting.

The issues of quality of service and effectiveness of service both refer to the reliability and predictability of a network. Without these qualities, a network is unusable for healthcare.

Question. The "lessons learned" from any endeavor are important. You mentioned in your written report that in your last phase of NGI support for fiscal 2001, a set of "lessons learned" will be developed. Would you please describe your planned activities to make these "lessons learned" available to others?

Answer. NLM plans to hold an open conference at which our contract award recipients will give scientific papers dealing with their "lessons learned". The presenters will be required to deliver to the NLM written papers dealing with these "lessons learned". These papers will be published by the NLM on the Web as well as in CD-ROM format. NLM will also try to place for publication in the appropriate scientific journals as many of these papers as possible.

Question. What do you believe are the current technological obstacles in advanced networking that limit the imaginations of your scientists? Does the National Library of Medicine's budget request for fiscal year 2001 reflect these long-term goals?

Answer. The inability of the current internet to guarantee quality of service and to provide a means for collaborative research certainly limits its scientific usage. NLM's FY-2001 budget reflects these long term goals.

RESPONSE TO WRITTEN QUESTIONS BY HON. BILL FRIST TO DR. RITA COLWELL

Federal Funding of Basic Research

Question 1. In your written statement you address the growing trend in the private sector of only funding applied research with "maximum short-term payoffs". Therefore, you suggest, it is the federal government's responsibility to invest in long-term basic research. Are there any types of basic research which you believe the federal government should not fund?

Answer. The National Science Foundation's approach to investments in science, engineering, and technology is guided by several fundamental principles. Few, if any, types of basic research are beyond the scope of the Federal government. In general, Federal R&D investments should: (a) sustain and nurture America's world leading science and technology enterprise, through pursuit of specific agency missions and through stewardship of critical research fields and scientific facilities; (b) strengthen science, mathematics, and engineering education; ensure their broad availability; and contribute to preparing the next generation of scientists and engineers; (c) focus on activities that require a Federal presence to attain national goals, including national security, environmental quality, economic growth and prosperity, and human health and well being; and/or (d) promote international cooperation in science and technology that would strengthen the advance of science, engineering, and technology. These principles apply to all Federal R&D investments.

Digital Divide

Question 2. Would you please describe NSF's ongoing research designed to overcome the digital divide and how it complements the work that the Department of Commerce is doing in this area?

Answer. Many NSF activities directly, or as part of other activities, address broadening access to information technologies. Research activities that address the digital divide include:

- NSF supports research on assistive technology that will allow fuller use of computing and communications technology by the visually or hearing impaired, those with mobility or dexterity problems and the elderly. NSF expects to provide $6.85 million for these activities in FY 2000 and has requested an increase to $12.0 million in FY 2001.
- In FY 1999 and 2000, NSF supported workshops to define the research agenda for understanding why women and minorities are under-represented in IT educational tracks and IT careers. Beginning in FY 2000, NSF will make research awards to understand the causes and provide a solid foundation for remediation to address under-representation.
- NSF's Next Generation Internet (NGI) program provides connectivity to high performance networks to a wide variety of research universities. Over 170 connections, including 40 to universities in ESPCoR states, provide demonstration projects of the capability and potential for high-performance networking. These provide researchers access to state-of-the-art network facilities to support their research as well as partnerships with other sites.

NSF is also active in many activities addressing the Science, Mathematics, Engineering and Technology education and workforce sectors that develop the knowledge and skills necessary to use information technology. Activities include:

- *Broadening access to the Internet.* In addition to the ESPCoR connections cited above, there are exemplary projects to develop networks for rural populations. The Urban Systemic Initiative and Rural Systemic Initiative programs have also funded projects in many areas that provide Internet access, as well as training to students, teachers and parents.

• *Minority institutions:* A recent $6.0 million award to EDUCAUSE will help minority serving institutions take advantage of the next generation of information technology and computer networks. The project will assist educators and students to effectively use databases, supercomputer centers, virtual reality and tele-collaboration facilities and other resources for teaching, learning and research.

• *Advanced Technology Education (ATE):* The ATE program provides students with laboratory experiences to prepare for careers in high technology fields. For example, the Northwest Center for Emerging Technologies at Bellevue Community College in Washington works with community groups to recruit non-traditional populations into information technology studies and careers. They have worked with hundreds of students from inner city schools, displaced workers, women, minorities and the disabled in programs to prepare their students for IT careers.

The Department of Commerce has numerous programs that address the digital divide issue. The NSF programs, which are more focused on science and technology research and on the specific needs of the science and technology education and workforce sectors, complement the Commerce programs by providing them with the technology that they can use in their community technology centers, technology transfer to industry, and in their teacher training programs.

Advanced Networking

Question 3. We have seen an increasing amount of overlapping activity in the past two years of the President's budget requests between advanced networking at the Department of Energy and the National Science Foundation. What does this overlap suggest about the roles of both agencies?

Answer. While it may seem as though overlap exists between NSF and the Department of Energy (DOE) in the area of advanced networking, the activities of the two agencies are well coordinated and complementary. The activities of NSF, DOE and other agencies active in networking are coordinated by the multiagency Information Technology R&D Working group, which is supported by the National Coordination Office (NCO), and reported annually. The IT R&D Working Group convenes a multiagency Working Group on Large Scale Networking that coordinates this specific area. Coordination goals include effective communication among agencies, avoiding duplication of efforts and expenditures, leveraging the research and accomplishments of agencies, and promoting cooperative programs where appropriate.

NSF funding for advanced networking includes two components: Advanced Networking Infrastructure (ANI) and Advanced Networking Research (ANR). ANI supports the university-based research community across the spectrum of science and engineering research areas through the vBNS (very high speed Backbone Network Service) which connects over 170 universities, including 40 in ESPCoR states. Research enabled on these networks includes tele-immersion, data mining, visualization of scientific and engineering data and calculations, and multimedia. ANR focuses on the fundamental research needed to expand the capabilities of communications networks; problems addressed include handling greater volumes of data, increased number of users, more complex protocols, new service types, and flexibility demands of mobile, nomadic and fixed environments.

DOE networking activities also include infrastructure and research components with an emphasis on linking heterogeneous (university-laboratory) networks and moving uniquely large (millions of gigabyte) data sets. DOE'S ESnet connects the Department's geographically distributed laboratories and provides access for university-based researchers to Office of Science facilities, such as synchrotron light sources, neutron sources, particle accelerators and supercomputers, through an interface with NSF's vBNS. DOE operates facilities that produce characteristically massive data sets for use by researchers at both national labs and universities. DOE networking research focuses on advanced protocols and operating system services for very high speed transfers and information surety to enable distributed, data intensive computing as well as the software framework ("middleware") required to support large-scale collaborative efforts among its laboratory and university researchers.

Broadband Last Mile Problem

Question 4. You stated that the "Broadband Last Mile Problem" remains a difficult dilemma.

a. What is NSF doing to solve this problem? Is similar research being conducted at other agencies?

Answer. The "Broadband Last Mile Problem," involves the high cost of "last mile" broadband Internet connections to end users, and in some geographical areas, the total lack of such services. The solution to this problem has a number of different dimensions, including some that require new technology and others, such as deregulation and promotion of competition, which are beyond NSF's scope.

NSF-supported research in broadband networking and communications has resulted in important technology transfer to the private sector, such as the Digital Subscriber Line (DSL) service, which is now being utilized by telephone companies to implement broadband Internet connections to the home. Current NSF and Defense Advanced Research Projects Agency efforts include research into wireless broadband networking and communications. It is anticipated that such research will lead to technical solutions for broadband Internet access in locations that are "hard to wire" and will promote the expansion of the competitive market for broadband Internet services.

b. In my own home State of Tennessee, Bell South invests more than $350 million for modernization and expansion of its Tennessee infrastructure every year. This includes widespread deployment of fiber optic lines and digital switching at every exchange. Is this a "problem" that the federal government should fix? Should we leave this issue for the private sector?

Answer. NSF's role in solving the "Broadband Last Mile Problem" is to fund research that may result in new technologies that the private sector can develop into solutions, It is clear that the solution will come from interactions between the public and private sectors.

NSF has a long history of partnering with the private sector to create and support leading-edge information infrastructures (like the NSFNET and the Next Generation Internet) for the academic community. Further, fundamental research across disciplines has provided an important testing ground for new, cutting edge networking technologies developed by industry. This has created an environment in which new products and services can be tested by the private sector before the introduction of new products and services into the retail market.

ESPCoR Involvement

Question 5. Dr. Colwell, can you comment on a growing interest on the part of non-ESPCoR states to become involved with the ESPCoR program as implied by Dr. Meredith's written testimony for the next panel?

Answer. NSF's ESPCoR program assists states that have historically received lesser amounts of federal R&D funding to improve the quality of science, mathematics and engineering research that is conducted at their colleges and universities. Three non-ESPCoR states have expressed interest in joining the ESPCoR program in order to improve their academic R&D competitiveness. While NSF is not seeking to add additional states to the ESPCoR program at this time, NSF's ESPCoR staff is working with representatives from these states to determine if their participation in the ESPCoR program is mutually beneficial and appropriate.

Research Transfer to Industry

Question 6. You mentioned in your written statement that there is a clear pattern of NSF-supported students bringing key insights to private industry. Can you discuss this pattern in greater detail?

Answer. Two studies of NSF support have explored the impacts of funding for graduate students on projects with a significant engineering component. A two phase study conducted by SRI International (full reports can be found at *http://www.nsf.gov/pubs/1999/nsf98154/nsf98154.htm* and at *http://www.nsf.gov/pubs/1997/nsf9756/nsf9756.htm)* examined the roles of federal research support in the development of six technologies: Magnetic Resonance Imaging (MRI), Reaction Injection Molding (RIM), the Internet, Computer Aided Design for Electronic Circuits

(CAD/EC), Optical Fiber for Telecommunications, and Cellular Telephony. The SRI report concluded:

> In our case studies of six engineering innovations, it is therefore not surprising to find that NSF emerges consistently as a major, often the major, source of support for education and training of the Ph.D. scientists and engineers who went on to make major contributions to each innovation.
>
> Among the six activities that NSF funds, it is this support of education and training that emerges most consistently across all our cases as a significant influence on the evolution of engineering innovation. In some cases (e.g., MRI, optical fiber) key contributors were supported in graduate school on assistantships paid by NSF grants or graduate fellowships; in other cases (e.g., cellular phone, CAD/EC) NSF-supported research grants trained engineers and scientists who were parts of industry teams tackling the technical problems that blocked an innovation's advance; in still others (e.g., CAD/EC) NSF-trained engineers became the entrepreneurs who created new firms and markets.

A third report assessing the benefits and outcomes of the NSF's Engineering Research Centers (ERG) program examined the performance in career jobs of students who had been supported in their graduate studies in center programs. The study (available at *http://www.nsf.gov/cgi-bin/getpub?nsf9840)* found that ERG graduates were significantly stronger in many job performance areas including: overall preparedness, contributions to technical work, depth of technical understanding, ability to work in interdisciplinary teams, breadth of technical understanding, and ability to apply knowledge and use technology. ERG graduates had more impact in activities, such as technology transfer and teamwork, that were emphasized in the ERG program.

NSF supported students have also brought insights to industry through their inventions and ideas. Some notable examples in areas relevant to NGI and Information Technology are:

- Marc Andreesen, while an undergraduate student at the University of Illinois—Urbana-Champaign working at the NSF funded National Center for Supercomputer Applications (NCSA), wrote the first WWW browser, Mosaic. Mosaic demonstrated the power of the browser concept for the WWW and became the "killer application" that popularized the Internet. Mosaic software was the basis for both Netscape and Microsoft browsers. Andreesen was one of the founders of Netscape Corp.
- Garth Gibson, while a graduate student at the University of California at Berkeley, developed error correction and detection for computer memory systems based on Redundant Arrays of Inexpensive Disks (RAID systems). The software and specifications form the basis of RAID 1 through RAID 6 standards for these systems and are the basis for modern storage systems developed by dozens of companies, and now a multi-billion dollar industry. RAID systems provide high performance and high reliability systems at lower cost than was possible before its development. Gibson is now on the faculty of Carnegie Mellon University.
- Srinivas Devadas, while a student at the University of California at Berkeley found deep connections between sequential logic optimization and testing and fault tolerant systems. The algorithms developed in his doctoral research are embedded in CAD tools supplied by numerous companies that are used to design integrated circuits. He is now on the faculty of the Massachusetts Institute of Technology.
- Brian Pinkerton, a University of Washington graduate student, used NSF supported equipment to develop the first full text WWW search engine, Webcrawler. This work is now incorporated into the Excite search engine and has influenced several other search engines.

These studies and individual cases demonstrate that NSF support of graduate students is critical to providing the highly trained workforce with advanced science and engineering skills and the abilities to use them in organizations at the same time that it supports striking innovations, such as web-browsers, that inspire entire new industries.

RESPONSE TO WRITTEN QUESTIONS BY HON. BILL FRIST TO DR. NEAL LANE

Question 1. Dr. Lane, we have talked about how IT is a driving economic force in the country, how important speed is to the Internet, and about the need for continuous federal investment in R&D. Would you describe for the Committee what the

Administration is doing to improve the technology transfer aspects of the IT research?

Answer: The success of the U.S. IT industry and the benefits that we derive from IT innovations today are a direct result of past Federal IT R&D investments and the successful transfer of new technologies resulting from these investments.

Much of the research funded by Federal agencies is implemented by researchers at universities and in the commercial sector. Funding provided to universities helps to educate students and support university researchers. Students graduate and move into industry, directly transferring their knowledge to private industry. In numerous cases, university researchers transfer their experience to start-up companies to rapidly make new capabilities available to the commercial sector. There are many success stories for this model of technology transfer. For example, Netscape began with a software package (Mosaic) originally written at the University of Illinois by an NSF-funded student. More recently, the Google search engine company was started by two Stanford students who took the results of NSF-funded research on digital libraries and built a commercial service using these ideas. Federally-funded commercial sector researchers can immediately apply the developed technology, software, and standards to commercial applications.

Federal IT programs also support testbeds for the demonstration and development of technology, software, and standards. Commercial participation in these testbeds provides immediate technology transfer. The Internet was developed by DARPA and NSF as a prototype that both involved industry as well as demonstrated the market potential of widely available data networking. Federal outreach programs such as publication of research results, presentations at conferences, and participation in joint Federal/university industry workshops provide timely awareness of new IT developments. More recently, the development of online "collaboratories" is helping people cooperate at a distance, making new results of Federal research available to a wide variety of people in many locations. Many agencies involve academic, industry and government scientists in planning activities for research; these expose industry to the capabilities of other sectors as well as calling attention to long-term industry needs.

In addition to these highly successful methods for technology transfer, new venues for technology transfer are being explored. These include preliminary experiments in open source distribution of software resulting from government-sponsored research. Industrial research collaboration is actively encouraged and funded by research agencies such as DARPA, NASA, and NSF and is a core feature of the NIST mission. This ensures a reciprocal leverage of research expertise in support of agency missions, while helping to develop technical standards which can be implemented by industry in near-term applications. Collaboration with other key contributing R&D performers—e.g. Federal laboratories and not-for-profit research institutions—is also important to ensuring technology transfer. We continue to carefully broaden merit-based participation in Federally-funded research and stimulate university-industry partnerships, while emphasizing long-term research agendas.

Question 2. A considerable portion of the federal investment in the IT domain is long-term research.

(a) Do you believe that private industry's rapid technological advances will catch or exceed the federal research?

Answer. Industry and the Federal government have complementary roles in IT R&D. Federally-funded research supports pre-competitive, long-term research that generates new knowledge and capabilities, the bank of ideas from which the private sector draws. Private companies are usually, and increasingly in the last decade, driven to short-term research for commercial advantage. They do not, as Federally-funded research does, explore new areas driven only by vision and/or agency mission needs rather than by understood commercial advantage.

While private research in a particular commercial IT area may be ahead of Federally-funded research, it is most often the Federally-funded long term research that produces the ground-breaking IT achievements when one considers the entire scope of IT research. Continued complementary investments by industry and government will help ensure our Nation's leadership in the information technology breakthroughs that are shaping our future.

More basic, yet compelling reasons for sustained Federal funding for long-term information technology are that these investments directly support the education and preparation of our young people for careers in IT research, as well as the training of workers to upgrade their skills to keep pace with a changing marketplace. Trained people are not just a by-product, but rather a major product of publicly supported research. This is why it is imperative that we maintain the health of our university teaching and research mission. We must retain research and teaching faculty in order to sustain and increase production of Master's and Ph.D. students in the IT disciplines. These skill levels are needed if the U.S. is to keep its innovative edge in international IT markets, and access to these skills must be broadened within our society.

(b) Also, how do you incorporate industry's advances into the federal research efforts?

Answer. Industrial technology is used to support many of the Federal IT programs. For example, the Next Generation testbeds are built on the cutting-edge services of commercial telecommunications providers (MCI, Sprint, AT&T, and QWEST). Private industry supplies essentially all production computing and networking equipment for these testbeds, which Federal agencies use to develop new technologies.

Many Federal agencies have advisory committees that include industrial members to ensure that they take advantage of industrial progress, as well as understand the needs of the industrial sector. The President's IT Advisory Committee includes industrial members, who provide review of and recommendations to the overall IT R&D research programs.

Federal agencies also include industrial researchers in their proposal review process, so that the agencies' research reviews reflect the state of the art in industry. In addition, there is direct collaboration of Federally-funded university researchers through various agency programs, such as the NSF awards supplements to CAREER awards, to match industry and state funding. In areas where industry researchers have the lead, the Federal agencies have funded those researchers to foster breakthroughs in key technology areas critical to Federal agency missions.

Question 3. Would you please explain the new activities established under last year's Information Technology for the Twenty-First Century initiative?

Answer. The Information Technology for the Twenty-First Century (IT2) initiative provides a critically needed augmentation to the base High Performance Computing and Communications (HPCC) programs to fund extensions of some ongoing HPCC research agendas and expansions into new research areas, as recommended by the President's Information Technology Advisory Committee. The U.S. research community responded to last year's call for research ideas with a flood of creative proposals, a demand which far exceeded the supply of new funding in agencies such as NSF and DOD. As a result, with FY 2000 funding, NSF will start 25 small research centers and five larger centers.

As in previous years, the proposed IT research portfolio is based on coordinated, interagency investments which leverage expertise across agencies to give the best returns on those investments, both financial and technical.

Research activities to be funded include:

- Expanding basic research on information technologies with a strong emphasis on software improvements. It is essential that we develop software that is dependable, resistant to intrusion, and inexpensive to build. Entirely new approaches are needed to move from today's computers to new machines that may link thousands or millions of individual processors.
- Approaches making it easier for people to communicate their requirements to computers and to understand the information the new systems make available. This will require entirely new tools for searching texts, pictures, and large sets of data. Special systems are needed for people with disabilities.
- Entirely new approaches to the design of computers needed to ensure that computational power continues to increase even when we begin to approach the limits of how small we can make electronic components. This will include exploring tools such as quantum computing or using DNA or other chemicals for processing data.
- Understanding the social, political, economic, and ethical issues raised by the transformations occurring in our economy and society as a result of IT. This includes attention to the increasing gaps in access to information tools and infrastructure that separate Americans along lines of race, gender, income, geography and physical abilities. Research is essential to understand and respond to these and other challenges created by an information rich economy.
- NSF has released a solicitation for a $36 million terascale computing system to ensure that the civilian research community can continue IT innovation through access to vastly more powerful machines than those available today. An FY2001 request for $45 million will fund a second terascale computing system and initiate up-

grades to maintain state of the art scientific computing facilities for civilian research.

Question 4. What percentage of the President's request for the IT initiative is designated for applied research? If Congress decided not to appropriate funds for IT applied R&D for the next ten years, would the private sector begin to fund this?

Answer. The traditional terms of "basic" or "applied" research are limited in their ability to describe the nature of scientific and technological research. For this reason it is difficult to determine a consistent categorization of basic and applied research across agencies. The President's Information Technology Advisory Committee urged increased funding for fundamental research, but also recognized the importance of federal support for applications development, testbeds, standardization efforts, and procurements of advanced computer systems. These activities are a vital part of the R&D portfolio. They enable progress in fundamental research by providing a means for applying new knowledge and a feedback process resulting in more effective research efforts and rapid adoption of new technologies. They also enable efforts requiring the talents of diverse communities of scientists and engineers.

The industrial members of the President's Information Technology Advisory Committee were unanimous in their opinion that industry cannot and will not invest in solving problems of importance to society as a whole unless such investments make sense from a business perspective. Given the intense pace of the IT marketplace, firms must devote the bulk of their R&D resources to shorter-term applied research and product development with clear commercial application. Nearly all human and capital resources must be focused on bringing the next product to market in order for a firm to be successful.

By funding a balanced portfolio of fundamental research, applications development, testbeds, standardization efforts, and procurements of advanced computer systems, the Federal government promotes the long-term health of information technology and demonstrate new technologies. The collaboration of universities, industry, and government laboratories allows Federal research to marry long-term objectives to realworld problems. Funding these activities through a variety of Federal agencies helps to leverage technical expertise throughout government and ensure broad-based coverage of many technological approaches to address a wide range of technical problems.